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AND

Transport of Fruit

IN THE

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E. A. GRIFFITHS.

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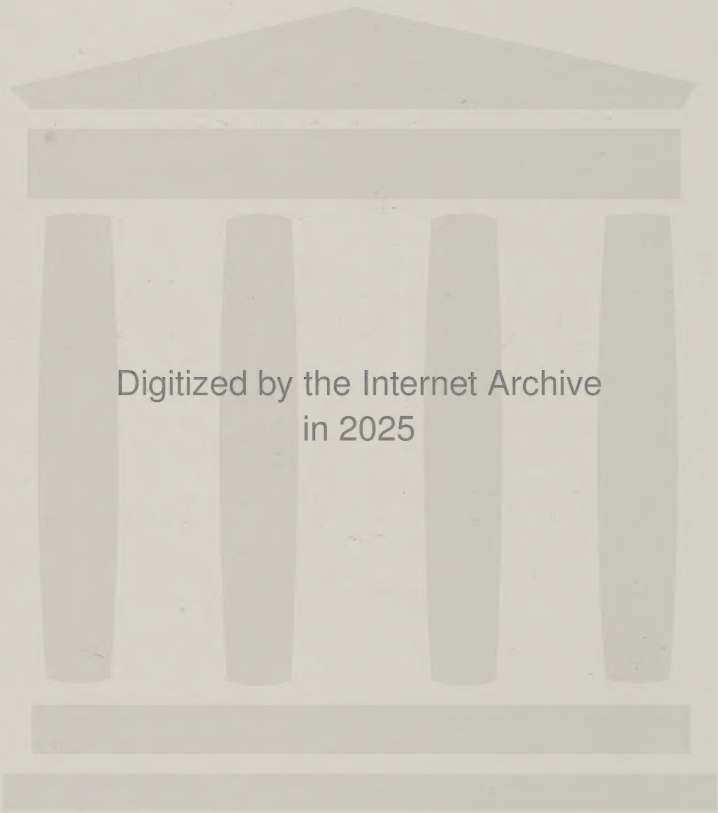
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Introduction.

In Science Bulletin No. 56 a general review was made of transport conditions at sea. Since this was published a new freight contract has been entered into between the Conference Lines and the Union Government. Under the terms of this contract we are able to co-operate with the Shipping Companies in applying the results of the published investigations. The new refrigerated space is equipped with self-contained brine batteries and air circulating fans capable at their maximum output of changing the air in the empty holds every two minutes. To avoid penetration of taint or mould spores all the insulation is faced with sheet zinc held in position by butt straps jointed down on mastic material. All air is delivered over the top of the cargo and air trunks are of galvanized iron with fixed apertures initially set by varying the number.

The usual suctions trunks as such have been eliminated because

(*a*) the cooling depends upon the proper distribution of cold air to all parts by the roof trunks;

(*b*) there is adequate channel for the return of the air between the dunnage on the floor. (A considerable thickness of dunnage is always used for fruit);

(*c*) This elimination of side trunks greatly facilitates stowing as carpenter's work in squaring up over trunks is not necessary. Suction trunks are therefore merely short narrow trunks across the bulkhead where the fan inlet is situated.

The results in actual practice with this new type of space have shown that in cooling down uniformity of temperature is rapidly attained and even with a certain amount of non-pre-cooled fruit a drop of ten degrees was effected in two and a half days. During the voyage extreme temperatures at any point do not amount to three degrees, these values being confined by observations of actual fruit temperature taken at Southampton by a member of the High Commissioner's staff.

There is still in use, of course, some of the old refrigerated accommodation which it would not be economical to convert, but the Shipping Company are as far as possible improving this on ships which are not likely to be made obsolete by new additions to the fleet in the near future.

Sea transport in itself, however perfect, will not counteract faulty methods prior to shipping, and the following bulletin is intended as a corollary to No. 56, as the study of packing, rail transport and pre-cooling is vitally important to the success of oversea fruit marketing.

The policy actuating the Government has been to provide facilities for pre-cooling and holding perishables at the main outlets from the Union.

Up to the present free choice has been granted to each and every exporter as to his port and low rates are applicable. This concession obviously cannot be maintained once equal facilities are available at different points, as the Railway Administration might be called upon to handle a consignment 800 miles further than necessary merely at the whim of the consignor. Again, these long hauls mean that rolling stock takes, say, eight days for a round trip as against five, and to maintain the service the capital investment in rolling stock has to be particularly heavy.

Undoubtedly, the solution of the traffic problem will be along the lines of demarcation of hinterlands for each port.

Whilst the Union is fortunate in not requiring refrigerated rail transport for the majority of its soft fruit when the necessity occurs the transit time is considerable and the requirements are stringent.

We have now in use satisfactory vehicles and I wish to acknowledge that the experimental work was carried out over the main routes of the South African Railways by Messrs. D. J. R. de Villiers and C. E. B. Cooper of this office and every credit is due to them for the able way in which the observations were made in face of difficulties and fatigue as the experimental trips occupied up to four days and continuous readings had to be taken.

The pre-cooling plants described in this bulletin were designed first and foremost around the handling facilities.

Although these were laid out on strictly scientific basis of calculated duty which they had to perform these requirements did not conflict with the provision of economical off-loading and transport through the plant.

The work was carried out departmentally and I have to acknowledge the hearty co-operation in the design of, first, Mr. J. Brown and then Mr. J. Prentice, who were successively Chief Draughtsmen. In the constructional work Mr. Paterson, A.M.I.C.E., and Mr. Ferguson, A.M.I.C.E., who were District Engineers at Capetown and Durban respectively.

The four refrigated lighters were built by Messrs. John Thornycroft, and I wish to acknowledge the able co-operation of Mr. W. W. Fawcett in connection with the design and supervision of the building.

There is one technical point in passing which might well be brought up for consideration and that is the lack of available data on heat transmission.

The fact that we were able to improve the heat transfer of the simple type direct expansion coolers by over 30 per cent. by simply alterating the orientation gives food for thought. The work of York Shipley in which the heat transmission is increased over three-fold in ice tanks is also most significant.

Most refrigeration design is mere empiricism and, unfortunately, the question of heat transmission is not simply an application of the classic researches of Stanton and others but more a matter of investigating into evaporating conditions of boiling liquid contained in a pipe and under conditions probably giving rise to frothing in the absence of free evaporating surface.

Investigation into this subject would well repay the effort.

In conclusion I wish to place on record my indebtedness to Dr. I. B. Pole Evans, Chief of the Division of Plant Industry, whose advocacy and unfailing support of a progressive scientific policy in transport is responsible for a great deal of the improvement that has been achieved.

For the numerous illustrations in the paper I am indebted to the excellent draughtsmanship of Messrs. C. E. B. Cooper and E. Wagstaffe.

Fruit Areas.

In order to understand the nature of the problem it is first necessary to explain the extent and demarcation of fruit areas in the Union. As a broad generalization, fruit growing may be divided into two main sub-divisions: (*a*) Deciduous Fruit, and (*b*) Citrus Fruit.

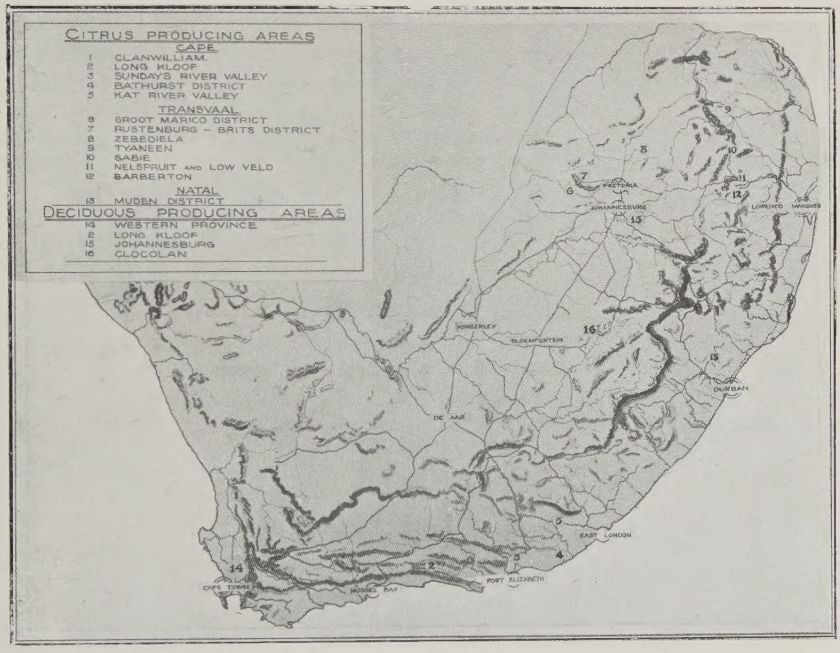


Fig. 1.—Fruit producing areas of the Union.

The term *Deciduous* is applied to all of the following varieties of fruit:—

> Pears, grapes, peaches, plums, apricots, nectarines, mangoes, melons, apples, avocado pears, grenadellas, tomatoes, prunes (fresh), pines, persimmons, pomegranates, quinces, gooseberries, litches;

whereas *Citrus* covers oranges, grape-fruit, naartjes and lemons; correctly speaking pineapples form a third sub-division, but in practice the export is small and this fruit is lumped in under deciduous. The harvesting period of deciduous extends from November to April, and citrus from May to September. Pineapples are a continuous summer and winter trade.

Approximately 28,000 shipping tons of deciduous fruit are exported in a season; 98.8 per cent. of this is grown in the western Cape Province and involves a railway journey varying from eleven to one hundred and fifty-three miles. The remaining percentage is made up of small consignments grown in the hinterland of the ports of East London, Port Elizabeth and Durban, with an amount of 0.7 per cent. (242 tons) grown in the Transvaal.

Obviously, the main bulk of the fruit can readily be transported over-night, leaving only the Transvaal fruit to be handled in refrigerated vehicles. This haul is approximately one thousand and three miles and it may take three days.

In the case of citrus fruit, the reverse state of distribution to deciduous holds good. The coastal areas produce approximately

Fig. 2.—Deciduous growing districts of western Cape Province

13,000 tons, whereas the Transvaal and Rhodesia contribute 45,000 tons.

The question of the " natural " port in the case of citrus, therefore, becomes an acute problem. An inspection of Table 1 will show the production of the different areas and appended on the right is the distance from each Union port. It will be observed that some of the distances to East London, for instance, are very short, yet in point of fact the fruit is actually shipped at Port Elizabeth or even Capetown. This is due, of course, to lack of facilities at the ports, the longer land transit is disadvantageous to the railway as a low export rate is

imposed and also risky from the point of view of fruit wastage, but will be unavoidable for some years to come.

Fortunately citrus is a winter crop and in addition withstands a much higher range of temperature. It is, therefore, feasible to transport all this fruit even over longer distances in ordinary ventilated trucks.

It is proposed to deal briefly in the following pages with the subject under the sub-headings, Grading and Packing, Transport and Pre-cooling.

In the case of deciduous fruit, all fruit is picked in a firm ripe condition. Picking is carried out by coloured labour and to avoid bruising the softer varieties of fruit are not touched with the tips of the fingers. The fruit as picked from the tree is placed in boxes or baskets lined with woodwool and taken to the packhouse on motor lorries or well-sprung mule wagons.

Packing Sheds.—The packing of all fruit, but more particularly deciduous fruit requires great care rather than skill. Bruising is the initial cause of ninety per cent. of wastage. Packing is, therefore, carried out by coloured labour under the strict supervision of white managers, although there is a tendency to employ all white labour for this work. Undoubtedly, this will eventually be more effiicent and economical as the output per capita with coloured labour does not approach that of the girl packers in the apple districts of Western America for instance.

There is no doubt that our labour is cheap in name only in many instances. Moreover, as expansion takes place labour becomes more scarce and by the laws of supply and demand more expensive without a commensurate increase in skill or output.

The packing sheds have in the past received scant attention, a shelter from the sun being all that was usually provided. There is a tendency to build more substantial structures, however, and special care is being paid to lighting, particularly in the morning and evening when the sun is low on the horizon.

The equipment of the packing sheds is, in the case of deciduos fruit, of the simplest possible kind, as soft fruit does not lend itself to the use of the mechanical devices so far available.

There are two or more grades of fruit. The designation and precise definition being laid down by a Grading Committee of representative fruit growers then approved by the Department of Agriculture and promulgated by the Governor-General as regulations under the Agricultural Acts.

In the case of deciduous the grades are laid down as: *Selected*, which shall be in sound condition, true to variety, fully developed, not too unripe, free from diseases, bruises, cuts or from any blemish detrimentally affecting their appearance; and *Choice* shall be in sound condition true to variety, fully developed, not too unripe and reasonably free from disease, bruises, cuts or other blemishes, but not necessarily to the same degree as required in the " selected " grade.

Fruit is packed so many of a given size to a box, the size being verified by means of a standard made of wood as shown in Figure 3.

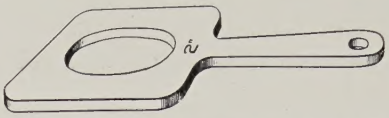


Fig. 3.—Wooden sizer for soft fruits.

The sizes vary slightly from time to time, those for 1928-1929 being as follows:—

	Extra Selected.	Selected.	Choice.
		Inches Diameter.	Inches Diameter.
Plums—			
Depending on variety	—	$1\frac{1}{4}$	$1\frac{1}{8}$
	—	$2\frac{1}{8}$	2
Peaches—			
All white flesh	—	2	$1\frac{7}{8}$
Elberta, etc	—	$2\frac{1}{4}$	$2\frac{1}{8}$
Nectarines	—	$1\frac{7}{8}$	$1\frac{3}{4}$
Apricots—			
Depending on variety	—	$1\frac{3}{4}$	$1\frac{5}{8}$
	—	$1\frac{7}{8}$	$1\frac{3}{4}$
Pears	—	2	$1\frac{7}{8}$
	—	$2\frac{3}{4}$	2
Pines—	Lbs. weight.	Lbs. weight.	Lbs. weight.
Cayenne	4	$2\frac{1}{2}$	2
Queen	$1\frac{1}{2}$	$1\frac{1}{4}$	1

Grapes.—All grapes are wrapped in tissue or other similar paper, the nett weight being clearly marked on the box.

Selected grades shall not weigh less than $\frac{1}{2}$ lb. per bunch, berries of good and uniform size, wrapped one bunch in each wrapper.

Choice grade may be wrapped two bunches together to make up $\frac{1}{2}$ lb. in one wrapper.

The average nett weight of grapes in one box is 10 lb.

Apples.—Apples are sometimes sized by hand, but most growers use mechanical appliances such as the " Cutler " grader. This device receives the individual apples in a canvas pocket and carries it along checking it repeatedly against a series of apples of selected weight until it corresponds and is dropped into the bin opposite the appropriate standard.

Citrus fruit, except on very small farms, is also mechanically graded. The fruit in this case is sorted in three grades: *Fancy*, *Choice*, and *Standard*.

Fancy shall be that which is free from all blemish and injury.

Choice shall be that which is sound in all respects save for slight blemishes or other injuries which in no way affect the quality of the fruit other than its exterior appearance.

Standard is that which is in all other respects equal to choice fruit but has been marked by hail or causes other than those specified below*, but not to such an extent as to be unsightly.

Each box is marked with a count, the size being determined as follows:—

Grapefriut....	Counts of	80	per box, average		diameter	$3\frac{1}{2}$ in.
	,,	96	,,	,,	,,	$3\frac{3}{8}$ in.
	,,	112	,,	,,	,,	$3\frac{1}{4}$ in.
	,,	126	,,	,,	,,	$3\frac{1}{8}$ in.
	,,	150	,,	,,	,,	3 in.
	,,	176	,,	,,	,,	$2\frac{7}{8}$ in.
	,,	200	,,	,,	,,	$2\frac{3}{4}$ in.
	,,	216	,,	,,	,,	$2\frac{5}{8}$ in.
	,,	226	,,	,,	,,	$2\frac{9}{16}$ in.
	,,	252	,,	,,	,,	$2\frac{1}{2}$ in.
	,,	288	,,	,,	,,	$2\frac{3}{8}$ in.
	,,	324	,,	,,	,,	$2\frac{1}{4}$ in.
	,,	344	,,	,,	,,	$2\frac{1}{8}$ in.
	$\frac{7}{8}$,,	360	,,	,,	,,	2 in.

Oranges.

There is a minimum weight stipulation. In the case of oranges of 64 lb. nett for counts 80-126 and 67 lb. for longer counts.

For grapefruit, the minimum is 54 lb. nett for counts up to 64 and 57 lb. for longer counts.

Naartjes are graded in a similar way as *Extra Selected*, *Selected* and *Choice*, the diameter being fixed as $2\frac{1}{2}$ in., $1\frac{1}{2}$ in., and less than $1\frac{1}{2}$ in. respectively.

The export of lemons is almost negligible, but they may be shipped in the standard citrus packages.

The mechanical graders or sizing machines used for citrus work on various principles; the problem is, of course, simplified by the fact that most varieties of oranges and grapefruit are more or less spherical and all that is necessary is some means of feeding the fruit through a varying width slot.

One device has two endless ropes which are arranged to travel along at a slightly diverging angle. The fruit is placed on at the narrow end and carried along until it falls through between the ropes into the appropriate bin.

In another type the fruit is carried by a flat canvas belt tilted at a slight angle; on the lower side and parallel to the belt is a rotating wooden roller of gradually decreasing diameter. The fruit moves along on the belt until it slips through under the roller into the right bin, the rotation of the roller assisting the movement. Variations of this device are available in the form of a machine in which the roller is replaced by small cross belts arranged at suitable heights over the carrying belt in such a manner as to roll the fruit off sideways when the size of the fruit corresponds to the set height of a particular cross belt. A few growers use a home-made arrangement consisting of a bicycle wheel set eccentric in a round opening, the fruit being fed on at the narrowest point and carried around by rotation of the wheel until it drops through. This device is not to be recommended in view of the excessive damage it sometimes causes to mis-shapen fruit. All the existing devices handle the fruit in single file and experiments are now being carried out by this Division on a type which will handle a

* Scale, fungoid or such injuries likely to cause waste.

greater volume per unit as an excessive number of machines are otherwise required to cope with the work of a big packhouse.

A typical modern citrus packhouse is shown in Figure 4.

Citrus fruit has to be stored up to a period of one week in order to wilt or cure the skin and this is done in the basement of the building shown. The fruit is then brought up by a conveyor and discharged on to rotating brushes which clean and polish the skin.

From here it is passed along on a wide canvas belt in front of sorters who remove blemished fruit or culls, then the fruit is passed on to the grader or sizer, and is discharged into bins. The packers again examine each fruit for insect stings or markings before wrapping and placing it in the boxes. The fruit is placed in the box according to a definite geometric pattern for the particular count.

Fig. 4.—"Delta" Citrus Packhouse. [*H. E. V. Pickstone, Esq.*

The lids are then pressed down and nailed, metal strapping being fixed around ends and middle for additional security.

Boxes.—There are four standardized boxes in use.

(1) Deciduous trays. These are made 18 inches long by 12 inches wide (outside), with varying depth from 2 inches to 6 inches for different classes of fruit. Apricots, for instance, being packed in shallow trays and grapes in trays 5 or 6 inches deep.

The end label is marked with the grower's brand, in the centre his name and number, the other end has no label but is stamped with the overseas agent's initials F. E. or S.A.F.E., etc., as the case may be. Two typical boxes are shown in Figure 5 as used for fruit from Government Experimental Farms.

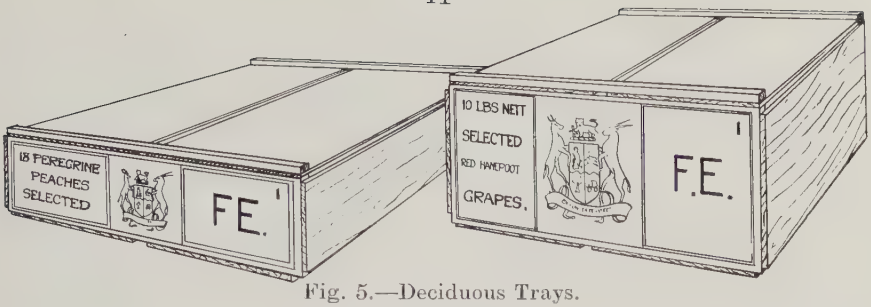


Fig. 5.—Deciduous Trays.

Cleats are nailed at each end of every box. These are coloured to denote variety of fruit, blue for plums, red for peaches, yellow for nectarines, green for grapes, black for apples, plain white wood for pears, mangoes apricots and strawberries.

(2) For apples a bushel box is used. This contains a 40 lb. bushel of fruit (actually about 45 lb.) Fig 6.

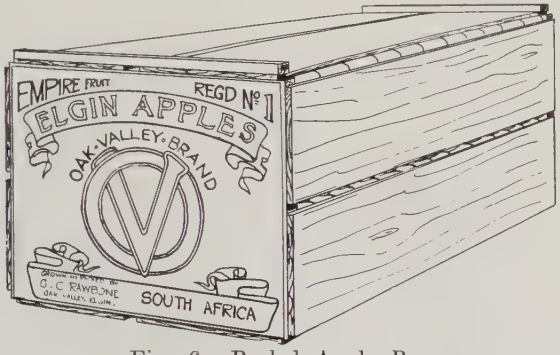


Fig. 6.—Bushel Apple Box.

This box is 18 inches long by $11\frac{1}{2}$ inches wide by $10\frac{1}{2}$ inches deep.

(3) Oranges are packed in boxes 12 inches by 12 inches by 26 inches outside. A centre partition is provided in this case for strength. The trade favours a bulge in the case of citrus and the lid is invariably convex. Some packers allow this bulge to become excessive by sizing slightly large for the particular count and the fruit under the bulge is consequently severely damaged in handling and transit.

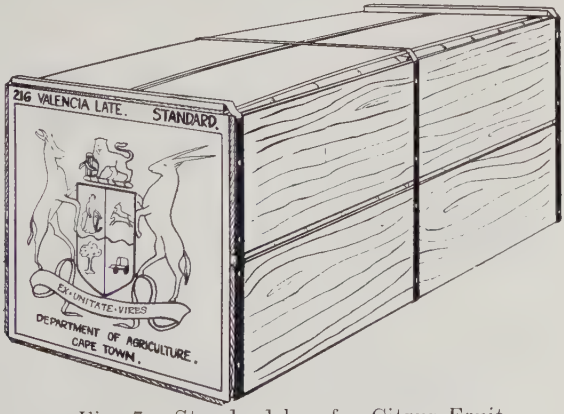


Fig. 7.—Standard box for Citrus Fruit.

To avoid this bulge damage as far as possible, citrus boxes and bushel apple or pear boxes are invariably stacked on end both in railway vehicles and ship's holds. The strength of the boxes is more than adequate for this method of stacking; in fact, our tests have shown that a typical orange box will withstand a one ton load with no deformation of the ends, apart from slight bulging of the sides.*

Rail Transport.

Loading.—Although the traffic is mainly night travelling fruit must be loaded into trucks during the day and some provision for protecting the trucks from the heat of the sun and bad weather has been found necessary.

Loading shelters are now more or less standardized in the "Ceres" type as shown in Figure 8, the road vehicles and railway truck being under shelter during all loading operations.

Fig. 8.—Railway shelter for trucks during loading.

Rail Vehicles.—As already stated the bulk of the fruit is either short transit or winter crop citrus and can therefore safely travel in non-refrigerated trucks.

The first vehicle used for fruit was a small four-wheeled box car imported in 1886. Many classes of truck have been put into commission since, all of them being closed vehicles with varying provision for free circulation of air. During 1926, however, the Railway Administration in conjunction with this Division decided to standardize fruit trucks and the design shown in Figure 9 was evolved. The ventilation is in the form of louvres all over the ends and sides. These are designed to throw off rain and the inner side of the slots are protected with fine mesh perforated metal to exclude insects.

The roof is provided with a radiation shield to minimize the effect of the sun's rays. All these vehicles have bogie underframes and vacuum brakes for express traffic.

From the point of view of stowing and economy of space the best

* This is equivalent to 27 boxes standing end on end.

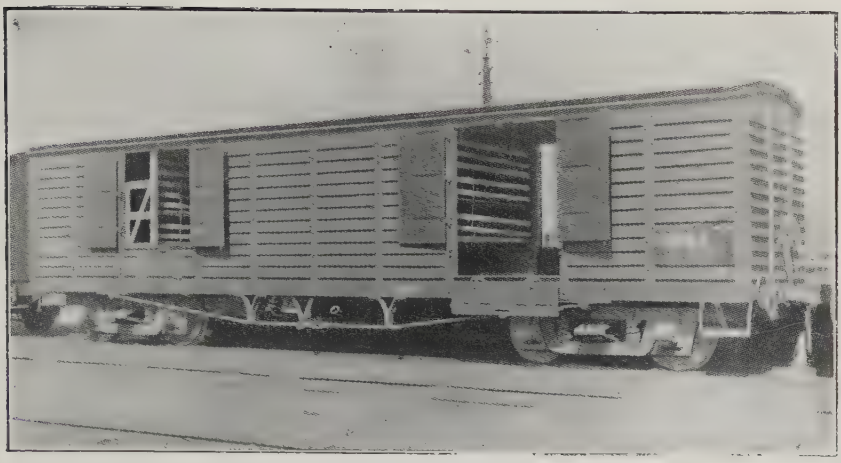


Fig. 9.—S.A.R. Standardized vehicles for fruit (ventilated type).

internal design of a truck is a plain level floor and straight sides. This gives a neat and rigid load. Unfortunately, trucks have to serve a dual purpose and carry a large quantity of grapes in baskets for local markets. Basket traffic cannot be stacked and racks are therefore provided for single layers of baskets. These racks, however, reduce the earning capacity of a truck by at least 25 per cent. apart from waste of time in loading. It is hoped that this traffic will eventually develop along the lines of standard containers to the advantage of all concerned.

Refrigerated Trucks.—Refrigerated vehicles are used for all long distance traffic of deciduous fruit, also from cold stores to ships (other than pre-cooling plants alongside the quay).

The type of truck first adopted was the universally used "end bunker" pattern, with improvements suggested by American investigators, that is an air space between the ice baskets and an insulated bulkhead to facilitate air circulation by convection. The cross-section of the truck is shown in Figure 10.

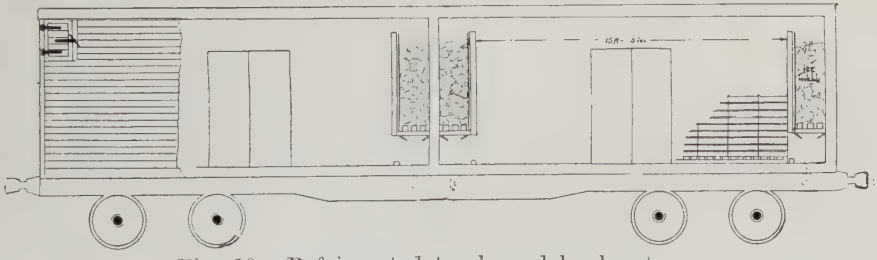


Fig. 10.—Refrigerated truck, end bunker type.

The ice, amounting to 3 tons is loaded through small doors into wire baskets and water formed in melting is drained away through traps in the floor. The fruit is loaded on a grid platform, the primary object of which is to safeguard the bottom layer from wet as the outlets persistently choke with foreign matter such as hessian fibre from the sacking used in handling the blocks of ice.

The temperature conditions obtained with these vehicles was

investigated by means of a portable electrical thermometer outfit as shown in Figure 11. The thermometers were wound with pure nickel wire and from twelve to twenty used in the different parts of the truck. The connecting leads were brought out to a junction box fitted with a selector switch so that any thermometer could be read without apening the doors or disturbing the conditions in any way.

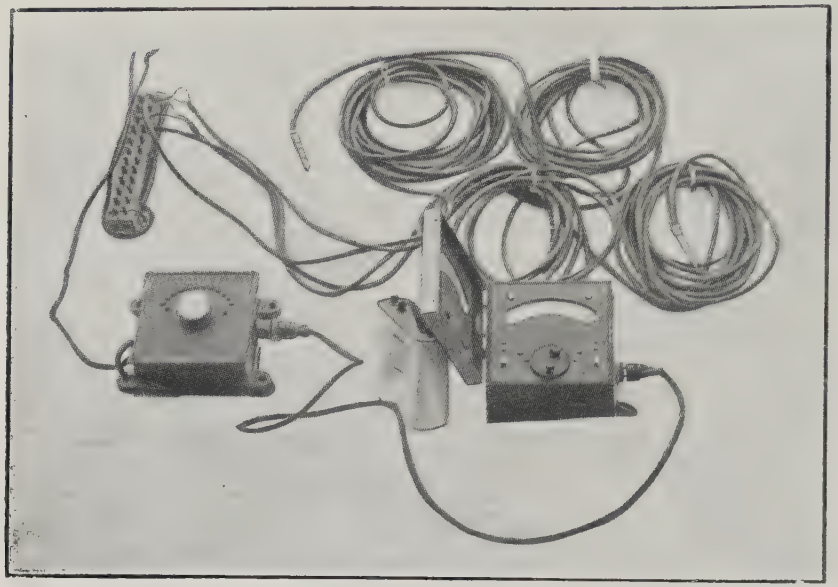


Fig. 11.—Portable electrical thermometer outfit.

The temperature of each thermometer was read at short intervals night and day.

A typical set of readings in shown in Figure 12.

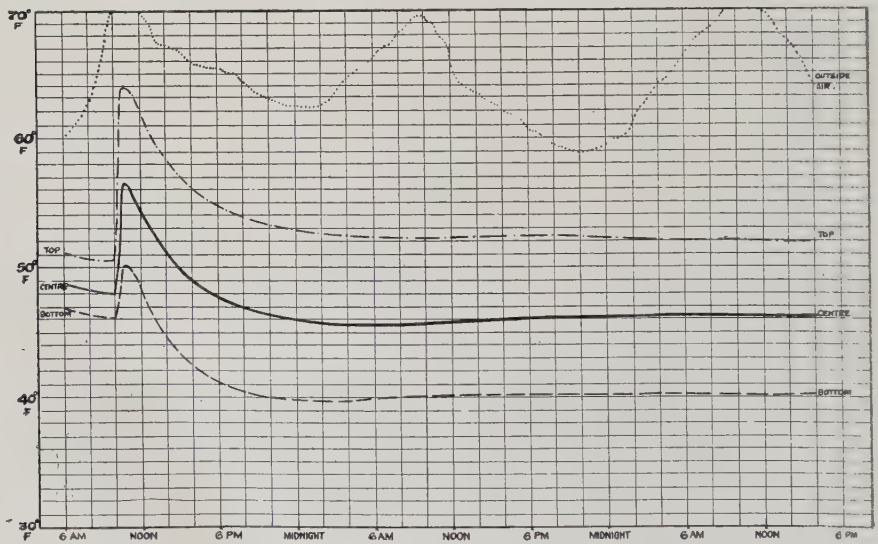


Fig. 12.—Temperature conditions in end bunker refrigerated truck.

It will be observed that the results are typical of those quoted in Trans-American practice. It is important to note that the quantity carried was less than half the capacity of the vehicle and even under these conditions temperature differences of 10-12° F. persisted between top and bottom layers of the fruit. This factor may not be of paramount importance where the fruit is disposed of immediately on arrival, but when it has to undergo another 6,000 miles sea transit then these variable conditions with the attendant variability in ripeness of the fruit cannot lead to satisfactory returns.

Experiments on salting show that the bottom temperatures can be considerably improved, but the differences persist from top to bottom. Numerous experiments have been made by this Division in an endeavour to improve the conditions.

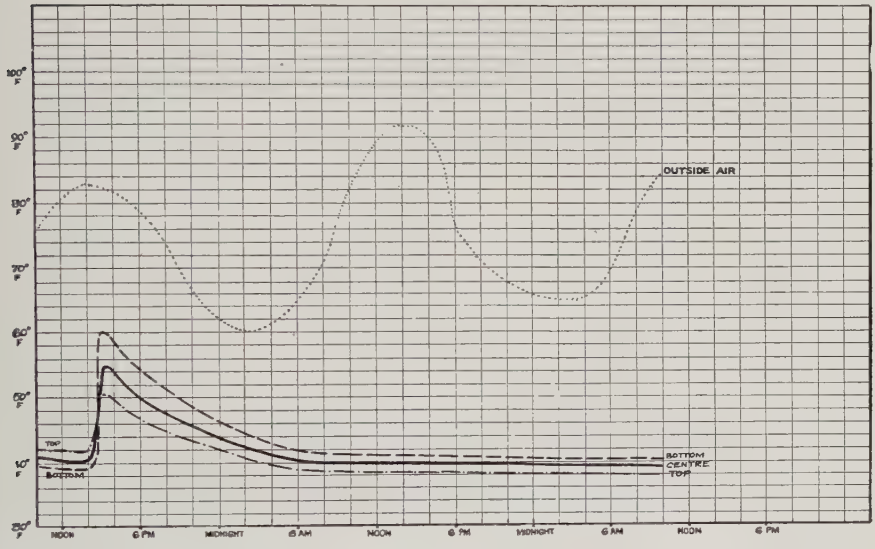


Fig. 13.—Temperature in roof bunker refrigerated truck.

The first point obviously was to secure uniformity. In light of other investigations it was decided to adopt top cooling although this had been unsuccessfully attempted in the past.

Special tanks were fitted under the roof with the underside pitched at an angle such that condensation would run along the surface to side gutters. Many initial difficulties were encountered. The ice tended to sway violently when the train shunted or travelled fast on curves and damage was caused to the tanks. This was overcome by breaking up the cooling into a series of eight tanks so that ice movement was restricted. Again ice was commonly dropped in from a height causing dents in the underside of the tanks. These points became starting places for condensation drip. The bottoms were, therefore, made of 10 gauge metal with traverse corrugations.

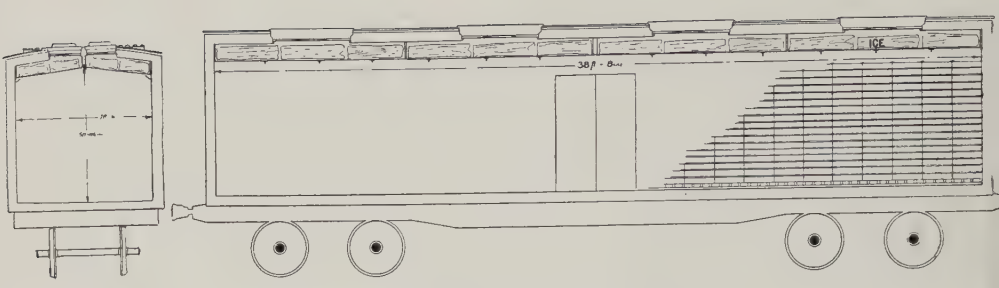


Fig. 14.—Roof tank refrigerated truck.

A cross-section of overhead tanker is shown in Figure 14.

The results for these trucks were a great improvement on end bunkers. Moreover, the limitation of load need no longer be insisted upon. These vehicles have repeatedly carried over 3,000 trays as against 1,200 in the older type of refrigerated vehicle.

A typical set of temperatures is shown in Figure 13.

Although the temperatures are better and load greater the consumption of ice was greatly diminished. This fact is due primarily to retaining the water in the tanks.

The uniformity of temperature permits the safe use of salt mixture to depress the freezing point and this has been used in practice.

A typical air temperature curve taken from a recorder placed in the bulk of the fruit is shown in Figure 15. The amount of ice used was 4,800 lb., to which was added an icing 700 lb. of common salt.

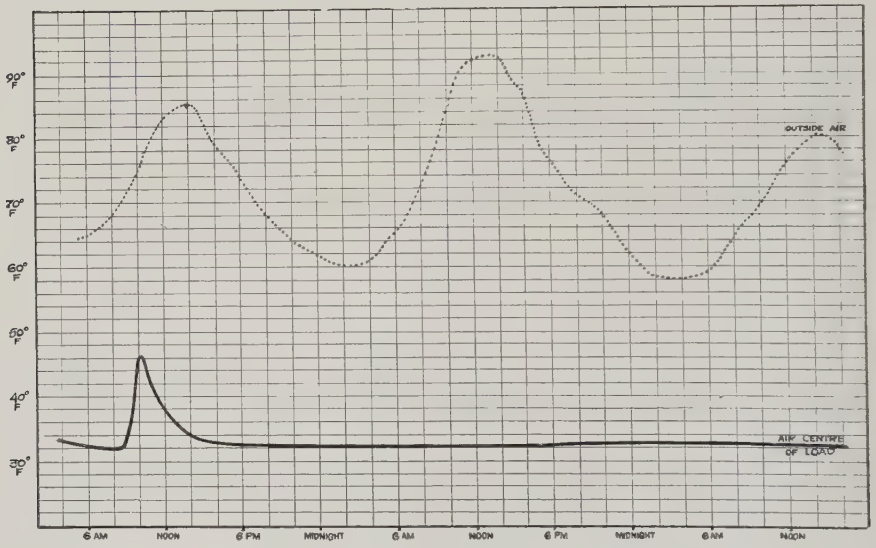


Fig. 15.—Recorder chart for roof tank refrigerator. Ice and salt in tanks.

The amount of salt is slightly in excess of actual requirements, but was used in order to depress the temperature to counteract the heating up of the pre-cooled fruit during loading, as this takes place

in the open and involves over two hours' work. It should be remarked that with ice and salt there is no difficulty with condensation as the tanks are frozen over with a thin layer of frost.

It is necessary with salt mixtures to shut the outlets of the tanks, of course, and in practice it is a considerable economy to keep the valves shut, even with ice alone, and retain the cold water, as it serves to economise ice.

The insulation of all the refrigerated vehicles is 4 inches thick, either slab cork or sugar cane fibre board such as "celotex" or "linofelt."

Experiments were made of a strictly comparative nature on two trucks to determine the effect of radiation shields as far as the roof was concerned. These shields being in the form of a false roof about two inches above the ordinary roof.

The vehicles were run coupled with same quantity of initial ice and fruit and temperatures measured. No preceptible difference could be observed in the temperature in either case but the ice consumption was reduced by 15 per cent. in favour of the roof shield truck. This fitment is, therefore, standardized on all classes of fruit truck, as it only involves an increase of about two inches in the total height of the vehicle.

Pre-Cooling Plants.

Experience has clearly demonstrated the necessity of pre-cooling fruit before shipment. Rapid and accurate cooling is the key to success in the case of soft fruit, and this cooling down involves a large expenditure of power which a ship is ill-fitted to provide.

Consider the condition without pre-cooling on an average ship lifting 2,500 tons. This fruit would be shipped around 90° F. The fruit would have to be cooled down after loading to 34° F. in 48 hours, say, as a maximum.

The total thermal units to be abstracted are 88 million. With the sea water temperatures prevailing on the voyage the horse power required would be over 300. A refrigerating plant of this size could not reasonably be accommodated on a fast passenger ship. Moreover, a very vigorous air circulation would be required involving another 100 H.P. and the cargo would, of course, be channelled and stowed with considerable waste space to allow free air circulation to carry the heat away.

Apart from pre-cooling there is another aspect.

Fruit could not in general be loaded immediately on to the ship and land storage would be essential as one day's exposure to the high summer temperature would depreciate the value of the fruit very seriously.

The pre-cooling on land has many advantages. It can be combined with handling facilities and the cooling effort is distributed almost uniformly over the week as compared with big intermittent efforts on board ship.

The geographical situation of pre-cooling plants is an important point in an extensive country like the Union. Long railway hauls are uneconomical as compared with sea transport and plants must be built to cope with the requirements of heavily producing hinterlands. On the other hand where the time factor is important such as in the case of deciduous fruit it may be better to accept a longer railway haul to reach the nearest port to the market if the ocean voyage from the port adjacent to the producing area is excessively long or if there is delay at intermediate ports.

A glance at the map, Figure 1, will indicate the general situation of South African ports.

Capetown is well situated to deal with all the deciduous area of the Western Province.

Then Port Elizabeth serves a considerable citrus area—Sunday's River, Pineries at Bathurst, and also the deciduous areas in the Longkloof Valley.

East London does not at present handle any large quantity of fruit, but it is geographically well situated to receive citrus from Fort Beaufort and Kat River, most of which at present goes through Port Elizabeth. These two ports, however, are open roadsteads and present peculiar problems of their own in handling fruit.

Finally, Durban has a coastal producing area of importance. It has also large citrus estates around Pietermaritzburg, but in addition to this it is the nearest point to the Transvaal and therefore shares with Capetown the Transvaal output.

Capetown.—With regard to Capetown the pre-cooling plant is erected at the Victoria basin which has an area of about 67 acres. There are three deep-water berths suitable for mail steamers. It was necessary to locate the pre-cooling plant on one of these berths for obvious reasons. From the point of view of railway traffic, the East Pier was finally selected. (Figure 16.) Being a mail-boat berth it was considered desirable to provide facilities for general cargo handling, and the ground floors of both sheds were reserved for this purpose. The pre-cooling chambers on the first and second floors, however, extend the entire length without a break, bridging the gap between the two cargo sections.

The sheds originally occupying the site were steel and corrugated iron buildings resting on 14 in. square wooden piles driven down to solid. There were 90 piles under each section. In view of the serious deterioration which had taken place at wind and water level it was decided to cut the piles down and build on a concrete grillage. The shed was then erected as a steel framed structure with columns at 16 ft. 3 in. centres in the two cargo sections and intermediate floors of reinforced concrete cast between steel joists. The outside walls are light panels of 9 in. brick and the whole building plastered in cement plaster for better weather protection.

All the interior is insulated with compressed cork slab set in Portland cement, the ceilings having additional thickness made up of granulated cork. Portland cement was decided upon as the best construction, seeing that only chilling temperatures were to be maintained.

Fig. 16.—Table Bay Docks. Position of Precooling Plant.

In view of the nature of the store it was decided to have a light coloured roof to reduce absorption of radiant heat, and asbestos cement was selected. For practical reasons, corrugated sheets were used, although we have found by experiment that flat material of a given colour is preferable to any corrugated form, owing probably to the absorption of heat from multiple reflection on the corrugations.

All asbestos compositions have the objection of giving wide joints owing to the thickness, and there is also the possibility of hair cracks and penetration of rain. The sheets were, therefore, laid on sarking boards.

. Wtih a view to isolating day-to-day consignments of fruit from each other thermally, it was decided to build small compartments, and the building is, therefore, divided up into 72 chambers. In

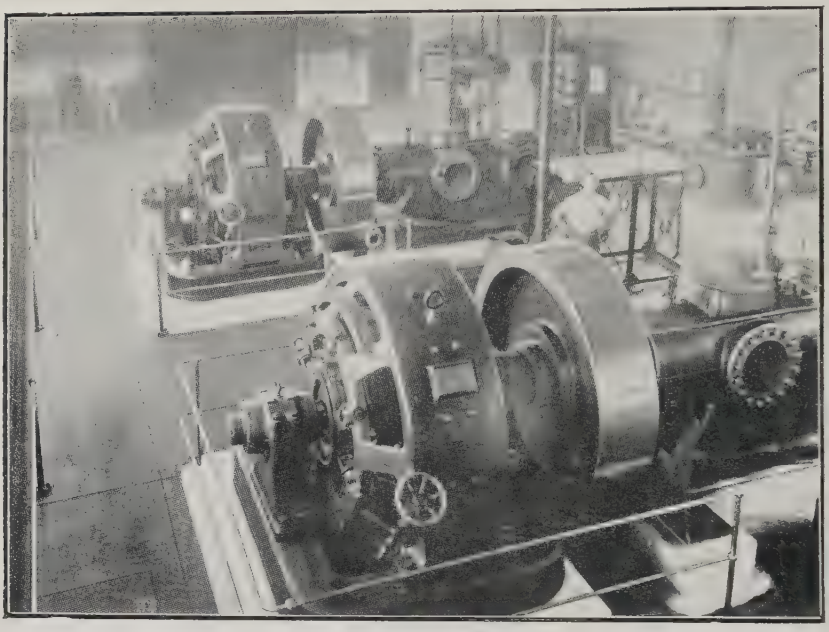


Fig. 17.—Engine Room at East Pier.

addition to this sub-division, it is necessary to avoid common air circulation, as the warmer fruit would still influence the cold if the same air coolers were used. The method actually adopted is a loop system, which may best be explained by considering one unit first. Each block of chambers is connected above to two air trunks, suction and delivery, extending the whole breadth of the group, and a cooling battery is built at each end. Starting with the first day's fruit and placing it in No. 1 chamber adjacent to A battery, the valves in the trunk are opened and B battery is used to cool the fruit. After about 20 hours, the fruit is cool, and A battery is started up. The valves are closed in the trunk and B battery diverted into No. 2 chamber, which contains the second day's fruit. Similarly on the third day, the A battery takes over the cold fruit in No. 2 chamber, and the B battery proceeds to cool No. 3 chamber. Thus, the sole function of

A battery is to maintain the fruit cold, and the cooling surface of the battery could be made comparatively small, although in actual practice the batteries are similar, thus permitting the operations to be reversed. This system, it might be thought, would permit of only one temperature being employed, but actually a control of several degrees range is possible by shutting the subsidiary valves, two of which are provided for each chamber. In practice, however, this method is not necessary, as there are five coolers distributed along the length of the building, and different varieties of fruit can thus be isolated at quite different temperatures; in addition, humidity, which is a vital factor, can be varied in the different sections.

Apart from pre-cooling, serious consideration must be given to handling of a perishable product like fruit. As already explained, there are at least two grades of each variety. Up to five per cent. of each grade and variety in every consignment must be inspected.

Fig. 18.—Partly loaded fruit trolleys.

Further, the regulations state that every box in the consignment must be stamped with the Government stamp after being passed. Then there is the tallying of all the fruit for the information of the railways, the inspectors and the pre-cooling staff. The system of handling must obviously make the inspection and tallying as simple as posisble. Various conveyor systems were considered, but it will be evident that the fruit would have to be stacked for inspection, then placed on a conveyor and carried into the store, stacked in the store, loaded on to the conveyor for transit to the ship, and finally stacked in the ship's hold. It is this repeated handling on to the floor and conveyor which is so costly, as it must be done with great care, supervision being difficult when 40,000 to 60,000 packages have to be handled each day. Some difficulties were also encountered with regard

to the conveyor to the ship. Most of the ships are fast passenger liners, and any suggestion of modifying the ship's structure was ruled out. Moreover, in the height of the season every available ship is utilized, and such vessels, not being equipped with special appliances or fixtures would render the conveyor system ineffective. Ultimately a bulk-handling system was evolved which met the requirements.

The simplest possible form of flat trolley or skid is used, measuring 7 foot 9 inches wide by 5 foot broad; the reason for choosing these dimensions being explained later. These trollies are marshalled in the receiving air locks before the fruit trains arrive, and unloading is carried out from the truck on to the trolley, the 5 per cent. inspection quota being placed on the floor for examination. The fruit

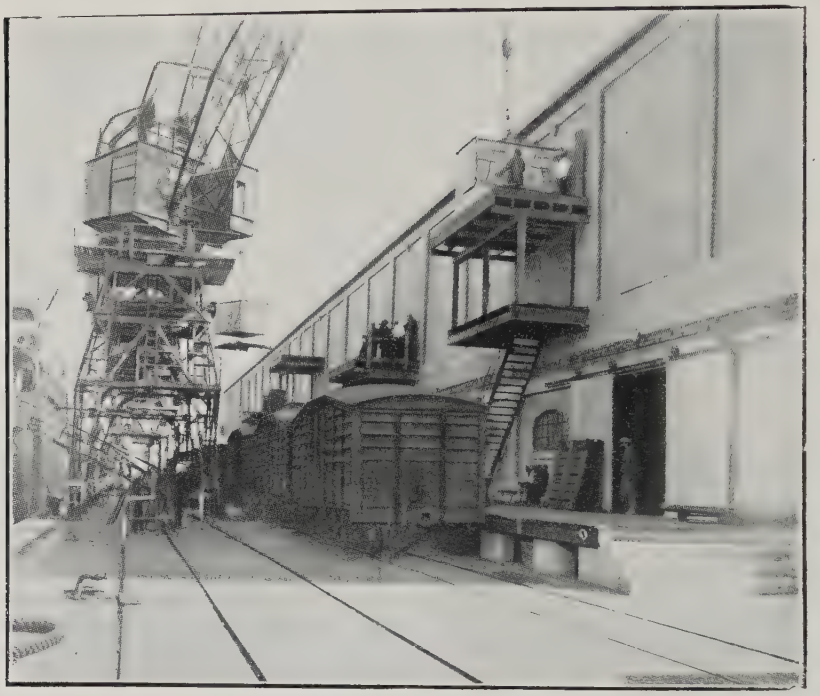


Fig. 19.—Trolleys being transferred from precooling plant to ship.

stacked lengthwise on the trolley, two boxes at each end, the middle tier of boxes being omitted, as shown in Figure 18. It is thus possible to read the end label of every box, and when the inspection is finished, to stamp each box. After this has been done, the middle tier is filled in and the trolley is ready for pre-cooling. The length of the trolley, previously mentioned, was made just sufficient to accommodate five tiers of cases for this reason.

From the air-lock, the trolley is carried up in automatic self-levelling lifts to the cooling chambers. Here it is traversed by an electric traverser, shown in Figure 20, and brought opposite to the appropriate door and pushed in, the capacity of the chamber being sufficient to accommodate 12 trolleys. One of the trolleys fully loaded with fruit is shown in Figure 20. As already stated, the

chambers are 15 feet 5¼ inches wide and allowing for air trunks and a passage way, trolleys 5 feet in width proved most suitable. The trolleys are loaded to a convenient height within reach of the workmen, about 350 to 450 trays or their equivalent being placed on each. The weight of the fruit and trolley must, of course, fall within the capacity of the quayside cranes and does not usually exceed 3 tons. One of the loaded trolleys being transferred from the cooling plant to the ship's hold is illustrated in Figure 19.

The trolley is designed for a maximum bending movement when supported by lifting beams at the extreme ends, and the under-frame is composed of two 4 in. by 2 in. channels, tied together by 4 in. by 2 in. headstocks at each end. The top of the trolley is of 1 in. pine boarding, and two light angle stiffeners are bolted along each side to protect the wood. The axles are 1¾ in. in diameter, and the wheels

Fig. 20.—Fruit trolley on electric traverser.

run on 1-9/16ths inch diameter roller bearings, both Hyatt and solid rollers being employed. Large diameter roller bearings were specified in view of the shocks imposed by landing on the decks with a heavy load. No lugs or lifting tackle are carried by the trolley, it being essential to make this as simple and cheap as possible, in view of the large number required. Moreover, the absence of projection is an advantage in passing through chambers, doors, etc.

Before leaving the question of handling, it should be stated that the fruit arriving in railway trucks is shunted into two large insulated air-locks situated at the back of the sheds. No. 1 air-lock is 221 ft. 6 in. long by 48 ft. wide, and No. 2 is 224 ft. long and of the same width. The working platforms at 2 ft. 10 in. above the rail level. All the walls and floors are insulated with 6 in. of slab cork, the plat-

form being surfaced with a heavily reinforced slab to distribute the concentrated load of the trolleys on the cork insulation. The ceiling is insulated with 9 in. of cork, and provision is made for cooling. No. 1 air-lock has 6,000 ft. of 1½ in. piping in elongated coils, each with a drip trough. Owing to a misunderstanding, No. 2 air-lock was supplied with the same length of piping in flat grids covering the ceiling. It was found necessary to fit individual drip trays under each pipe, but with a careless operator there is always a possibility of cooling the drip trays below the dew point and causing them in turn to drip. Apart from the cost, flat grids are not considered suitable for this class of work. The functions of these cooling grids are two-fold, the first being to reduce the temperature when the outside atmosphere is at about 100° F. and thus to check the ripening of the fruit. A matter of hours appreciably affects peaches at this temperature. The second function is to avoid the necessity for overtime working when fruit trains arrive late, the practice being to close down the air-lock and cool the building, including the fruit trucks, until next morning. This procedure has proved most satisfactory from the point of view of fruit condition.

For manipulating the trolleys in the air-lock an electric traverser is provided, and erected in the position it would occupy when the lower floor cargo sheds are ultimately converted to pre-cooling chambers to meet future expansion. This traverser, which is similar to that illustrated in Figure 20, runs along the back of the air lock platform and feeds the two lifts. The traversers, one of which is provided in each air-lock, run on a track with rails at 6 foot centres, and are driven by 5 h.p. motors through double-reduction spur bearing. A dead-weight brake and also a magnetic brake are fitted. The controllers are in duplicate for either direction of travel, and on one side of the traverser is fitted a small capstan, of 2 h.p. separately controlled. This is used for towing trollies out of the chambers on the shipping galleries or out of the lifts, but its use has proved unnecessary as full trollies can be handled by one man.

The cooling duty necessary in a plant of this nature is divided into that required to keep the building cold and that for pre-cooling. For the former, a simple estimate can be made on the assumption that the external walls are at an average temperature of 90° F. and the roof at 120° F. The total requirement under this heading is quite small compared with the pre-cooling. For the latter, taking deciduous fruit first, the boxes vary very considerably, only 2 lb. to 4 lb. of fruit being carried in peach boxes, whereas grapes and pears have a net weight of over 10 lb. per box. Taking, however, a fair average weight of 6 lb. and assuming the box and wood-wool packing to weigh 3 lb., with a specific heat of 0.9 for the fruit and 0.3 for the wood, the cooling required for 50,000 boxes a day from 90° F. to 34° F. is 27,100,000 B.T.U. This fruit is accommodated on 125 trollies, each trolley weighing 550 lb., and the cooling required amounts to 454,000 B.T.U. Citrus fruit is a winter crop, and the cooling required is, say 10,000 boxes, each box, with the fruit, weighing from 75 lb. to 80 lb. The temperature on arrival is 60° F. and this has to be reduced to 40° F., so that the duty required is 13,120,000 B.T.U. a day, or roughly half that necessary for deciduous fruit. Allowing for average moisture conditions, approximately 1 grain per cubic foot is frozen down at the mean temperature during

pre-cooling operations. This involves 29,000 lb. of water a day, at 203 B.T.U. per pound, a duty of 5,800,000 B.T.U. Allowing also for the heat absorbed through the insulation, and heating effect of the fans, a covering figure, 120 tons normal rating or 38,000,000 B.T.U. per day was specified for each of two machines, each being a duplicate of the other in every respect.

The machines are of the vertical type with two cylinders of 16½ in. bore and 12 in. stroke, running at a speed which can be varied from 140 to 220 r.p.m. They are electrically driven, the motors being supplied with continuous current at 500-550 volts, as used for the crane and wharf supply. Two main feeders are installed, one of 1 sq. in. cross-section, the other of ½ sq. in. cross-section, the lighter cable being brought under the water across the Dock entrance so that the circuit is looped back to the sub-station as a precaution against break-down. The compressors deliver to duplicate atmospheric condensors, mounted on an elevated concrete trough, main stop valves and cross-over valves being inserted above the oil separators. Sea water is pumped from the sea by two centrifugal pumps. Considerable trouble was at first encountered by erosion of the shaft and impeller owing to incrustations formed in the pipe breaking away and passing through the pumps. The fitting of Staybrite steel shafts and impellers, however, ultimately eliminated the difficulty. The high pressure liquid ammonia distribution is through two 1½ in. bore pipes to the five batteries and a 1 in. bore pipe to the two air-locks, a subsidiary hot-gas pipe is also laid for assisting the thawing down of snowed coils. The liquid ammonia condensed in the thawing operation is led to the other batteries in service, otherwise it might form liquid slugs in the compressor suction main.

There are, as already stated, five cooling batteries. Nos. 1, 2 and 3 are constructed with 16 sections and a total length of 8,000 ft. of 2 in. bore pipe. Each battery is designed to transfer, at normal load, 10,000,000 B.T.U. per day into the circulating air. The original intention was to construct these batteries with coils traverse to the air flow in view of the promising experimental results we had obtained with this pipe arrangement, but in view of the urgency of the first part of the construction and certain technical difficulties, longitudinal coils of the usual pattern were made. In the case of Nos. 4 and 5 batteries, however, special effort was made to obtain traverse coils, and these two batteries were built of 10,000 ft. of 1½ in. bore with 12 distribution headers (i.e. approximately the same surface as the other coolers). A rough comparative test of the performance of the two designs is given in the accompanying table. The figures, however, are only approximate.

	Cubic Feet of Air per Hour.	Air Temperature Difference.	Superheat of Gas.	B.T.U. per Hour after Correction for Water Deposited.
		F.		
Longitudinal coils....	1,620,000	10·5	10·0	387,000
Traverse coils.....	1,440,000	16·5	10·5	568,800

It was difficult, for instance, to maintain the same superheat in the two coolers, as the expansion valves could not pass sufficient liquid ammonia in the case of traverse coils. Moreover, the test had to be carried out by passing atmospheric air through and any variation in outside temperature introduced complications since the specific heat of the cooling coils affects the results; the coils weigh 25 tons, so that their heat capacity is appreciable. Lastly, the advantage of traverse coils could be better demonstrated with high air velocities as the cooling varies as $\sqrt{\text{Vel}}$, that used in the tests being actually about 450 feet per minute.

In estimating the pre-cooling air required, the thermal transfer necessary is 38,000,000 B.T.U. less the heat equivalent of the snow, or, say, 32,000,000 B.T.U. a day.

Fig. 21.

Assuming the specific heat to be constant and working with a temperature drop of 14° F. at the commencement of pre-cooling, falling to 2° F. at the end, or a mean temperature drop of 8° F. for calculation, the quantity of air required is 16,650,000 lb. a day. Assuming 12 cu. ft. per lb., the volume required is, approximately, 200,000,000 cubic feet a day. The fans selected were three with capacities of 25,000 cubic feet per minute, one set of two fans handling 36,000 cubic feet per minute, and one of 35,000 cubic feet per minute in capacity, the total capacity thus amounting to 208,000,000 cubic feet a day. In actual practice, it is possible to exceed the individual duty considerably, a reserve being necessary for emergencies since the load is not evenly balanced over the batteries.

It should here be stated that the bulk-handling system described above, has been carried experimentally a stage further since the plant was brought into operation. Empty trollies are now forwarded to the growers and loaded with cases of fruit at the inland sending stations.

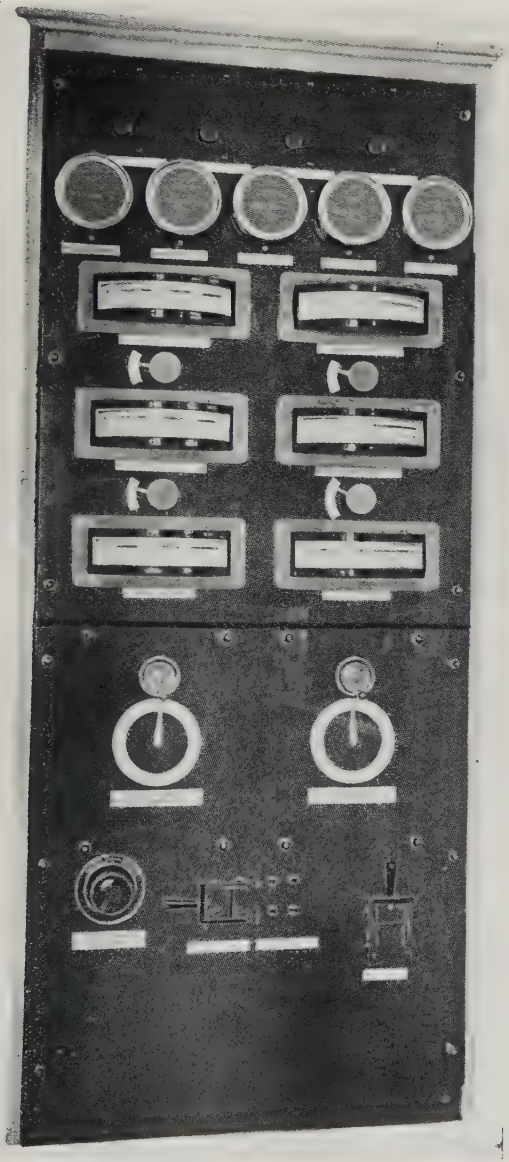


Fig. 22.—Thermometer Panel.

They are then pushed into special railway trucks in which they are transported to the air-lock for the pre-cooling station. Here the trollies are wheeled out of the trucks, one of which is illustrated in Figure 21, and transferred to the pre-cooling chambers without any

handling of individual cases. This practice will, of course, only be carried out in connection with the larger sending stations, where the necessary inspection can be carried out before putting the fruit on rail. This has the obvious advantages of reducing the amount of handling and avoiding congestion at the pre-cooling plant.

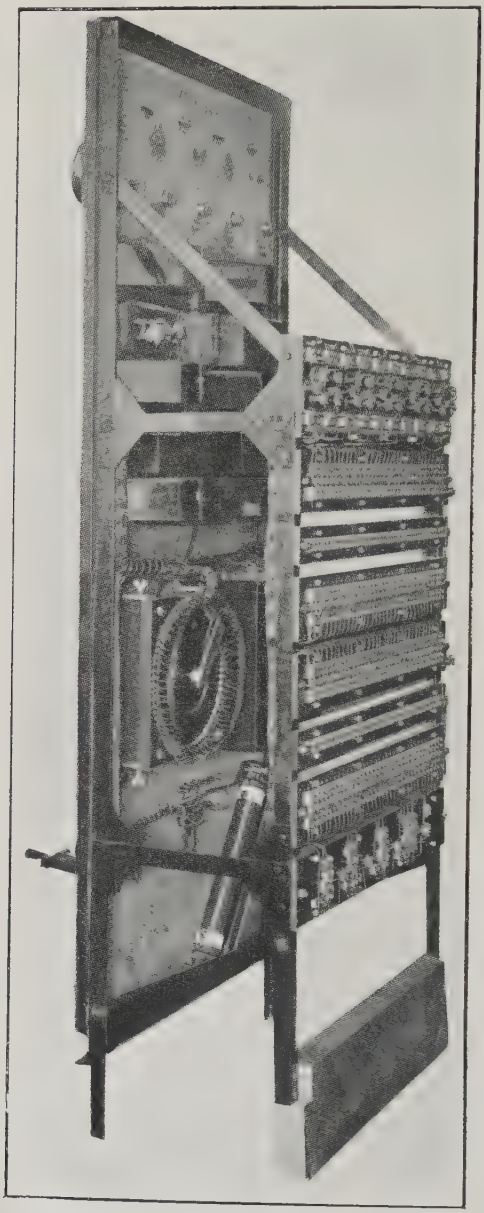


Fig. 23.—Thermometer Connections.

Temperature Control.

The temperature of the chambers is controlled by varying the quantity of ammonia evaporated, the speed of the fans and the adjustment of the air valves leading into the different chambers.

Regulation is facilitated by the use of a central temperature indicating switchboard.

The thermometers, of which there are 77, are situated one in the out-going air from each cooler and one in each chamber near the exit. The coolers are regulated to ensure that the air leaving is not more than $\frac{1}{2}$° F. below the temperature specified for the fruit. The thermometer in each chamber indicates approximately the stage at which the fruit has cooled down as the outlet air will then be at the temperature of the fruit and it is quite safe to transfer the air circulation to chambers which are already holding fruit.

The thermometers operate on the Wheatstone Bridge principle. Each resistance head being wound with pure nickel wire properly annealed and aged (i.e. all mechanical strains removed by submitting to a wide range of temperature). Each head is made up to a specified resistance of 100 ohms at 32° F. The connecting wires are brought to a large cast-iron junction box in the main building and from this point a multicore cable is led back to the engine room. Lead covered wire is used throughout as rubber covered has a tendency to perish and crack.

On the board there are six selector switches, two of them for the chambers, and the other four (two-way each) for air batteries, allowing for additional coolers in future extensions.

Indication of the out-going air temperature is always visible without operating the main selector switches although there are not the same number of indicators as coolers for the reason that all coolers are not working simultaneously.

The connections at the back of the board are clearly shown in Figure 23. The upper panel carries the Wheatstone Bridge circuits and the small bobbins shown are the ratio arms and the counterbalancing resistance.

The terminal connections below have attached a small resistance bobbin.

The amount of wire in this bobbin is adjusted when the installation is made to compensate for the varying length of the connection leads to the different thermometers. This is effected by short-circuiting the thermometer with the connecting strip in the terminal box and setting the indicator with a sandard resistance in circuit.

It will be realized that the indication of the thermometers operating on this principle depends upon the voltage applied to the circuit and, in fact, varies directly with this voltage. An indicator of the identical construction is, therefore, included on the left-hand corner of the switchboard to show the voltage of the battery. This pointer is maintained at a definite fiducial mark and any fluctuation in the battery is immediately visible. This is considered an essential refinement in preference to the older method of merely setting the instruments from time to time by switching on to a particular fixed resistance value.

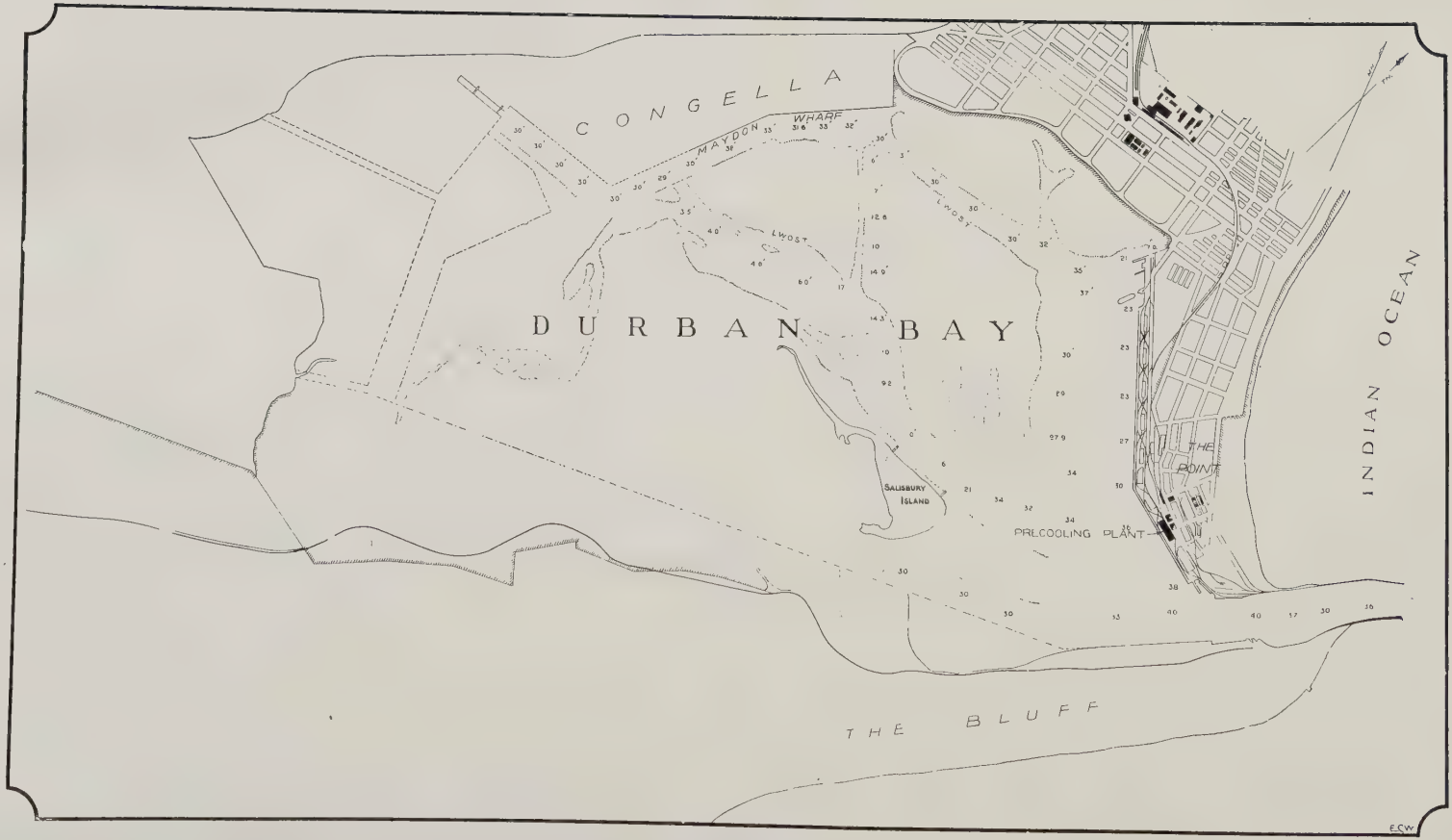


Fig. 24.—Durban Harbour, showing precooling plant at Point.

ape it.	Shaddocks.	Naartjes.	Lemon	Total.	Distance by Rail to Port.			
					Cape Town.	Durban.	Port Elizabeth.	East London.
1	—	2	—	1,870	1,041	608	—	—
	1	5	—	1,984	998	566	—	—
82	—	—	5	7,794	1,070	579	—	—
—	—	—	—	138	955	523	—	—
	—	—	—	217	1,065 1,083	574 592	— —	— —
	—	54	—	3,780	1,139 1,160	648 669	— —	— —
	—	—	—	93	1,262 1,345	776 854	— —	— —
	—	—	—	1,184	1,286	795	—	—
57	—	—	6	684	1,326	835	—	—
57	—	8	—	432	1,219 1,254	729 764	— —	— —
67	—	3	10	1,950	1,203	713	—	—
77	—	—	—	2,772	1,167	677	—	—
00	—	43	—	3,481	1,209 1,215	719 722	— —	— —
	—	—	—	22	1,172	682	—	—
	—	—	—	24	—	376	—	—
3	—	66	14	90	—	—	—	—
	—	—	—	180	—	—	—	—
13	—	—	—	4,008	—	71	—	—
08	—	105	43	948	—	—	—	—
23	—	—	—	237	177 107	— —	— —	— —
	—	—	—	281	192	—	—	—
	—	6	—	243	Via Port Nolloth by sea.			
	—	1	—	227	431 249	— —	312 —	— —
3	—	8	—	1,194	—	—	50	—
12	—	35	1	1,423	—	—	50	—
66	—	—	—	978	—	—	21	—
22	—	—	—	1,095	—	—	32	—
2	—	—	1	453	—	—	106	—
15	—	—	—	2,086	782	—	196	105
9	—	—	—	129	732	—	145	193
6	—	—	—	8,312	1,659	1,462	—	—
77	—	—	—	254	To Lourenco Marques.			
00	1	336	80	48,563				
00	14	23,558	1,436	879,861				

10	—	970	—	50,841
98	—	57,918	2	940,594

The current is supplied to the outfit from two large accumulator batteries. Small cells have in the past proved extremely troublesome, but these large capacity cells have been very satisfactory and remain constant for days at a time.

The air quantities are indicated by counter mechanism of the Harding type operated by intermittent contacts made by Robinson cup anemometers placed in the air ducts. The number of thousand cubic feet per minute being an indication of the duty of each battery.

The complete outfit was built to our specification by Messrs. Siemen's Bros., Woolwich, and has maintained a consistent accuracy within the guarantee of $\frac{1}{2}^{\circ}$ F. since it was installed. The only minor difficulty that has occurred is dust and moisture accumulating on the selectors. These are such a vital part of the equipment that we would recommend air-tight cases to protect them in future.

Durban Pre-cooling Plant.—As already stated, Durban is geographically well situated to handle the Transvaal traffic; moreover, it has also to deal with a considerable volume of fruit grown in the coastal belt and areas near Pietermaritzburg.

The opinion is held in the Transvaal that the export of meat will eventually materialize and this would naturally pass through Durban. The plant at this port was, therefore, designed to handle fruit, chilled and frozen meat, butter, cheese and eggs.

With regard to the position of the store there were two alternatives, (*a*) to build at Congella in the newly-developed industrial area, or (*b*) to reconstruct an existing shed at the Point as a dual purpose building.

The first proposal had the disadvantage of poor foundations and a long distance transfer of the steamer through a narrow dredged channel, whereas (*b*) had the drawback of a congested site and of passing all rail traffic through the town and across streets on single lines of rails. On the other hand it was felt that the highly perishable traffic involved would for many years at least be conveyed by the fast passenger liners and these would not transfer to a Congella wharf to work fruit alone as their loading time is invariably limited and they endeavour to work all cargo simultaneously.

This view has since proved correct, inasmuch as a ten years' contract has been entered into between the Government and the Conference Lines to lift the bulk of the fruit in the mail boats. The deep water berth used by the bigger ships was B shed, and this building is the one reconstructed.

The plant is built as a general purpose structure incorporating the fruit handling system used at Capetown.

There are three floors, the ground floor being used for general cargo with a section partitioned off as an air-lock. The first and second floor being divided into three, the centre section consisting of cold chambers.

The general plan of the building is shown in Figure 25.

The structure is on ground partly made up towards the quay wall and the foundations were, therefore, laid on piles in the new ground. The main columns are steel, spaced 15 ft. 3 in., centres and the panels are built in 9 in. brick. All the floors are reinforced concrete and the roof is corrugated asbestos laid on sarking board.

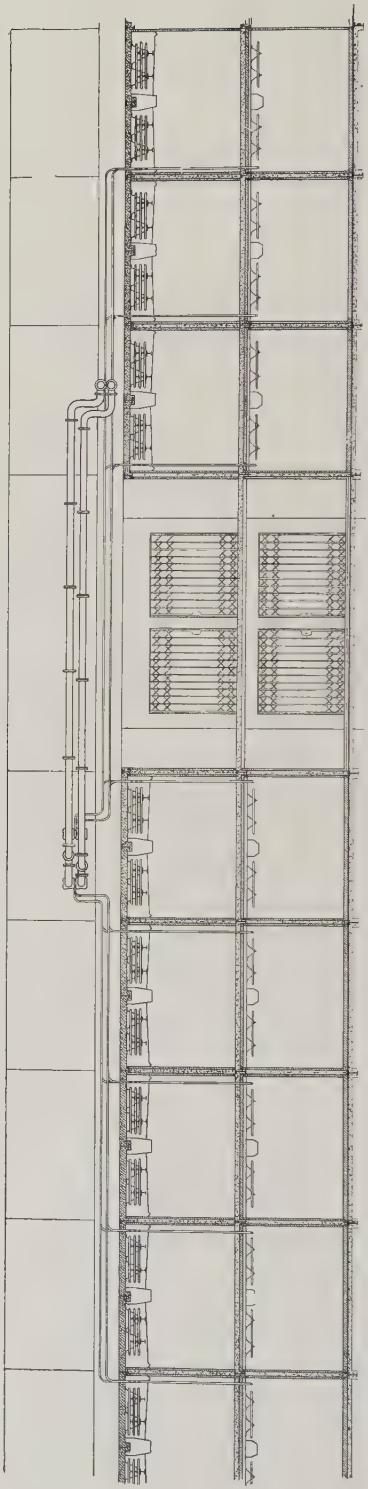


Fig. 25.—Arrangement of chambers.

There are sixteen chambers, eight on each floor. These have brick partition walls insulated on each side with a double layer of cork, a top and bottom chamber forming a pair completely isolated from adjacent chambers. For fruit pre-cooling eight fans are provided, one for each pair of chambers, the capacity at normal speed being 10,000 cubic feet of air a minute. The cooling battery consists of three layers of grids on the roof of the upper chambers, the grids being boxed off by flat trays underneath.

For meat or " still air " conditions the trays are removed and one set of grids used. In the lower chamber a roof delivery duct and side suction ducts are provided interconnected to the top chamber ducts, so that top and bottom chambers are operated by the fan and battery.

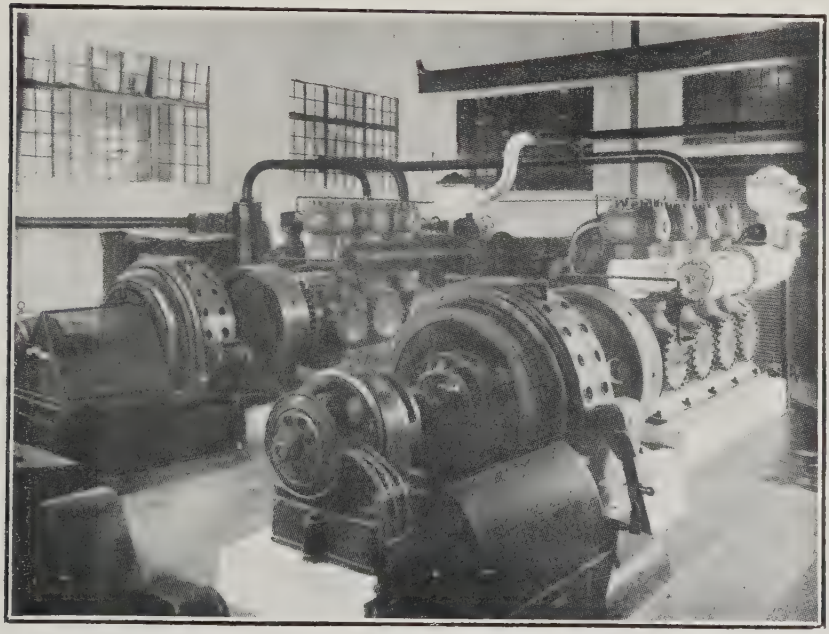


Fig. 26.—Engine Room at Durban.

The lower chamber has a separate set of roof grids for meat working. These are made up in diagonal pattern with counter flow in order to secure the greatest uniformity of temperature for chilled meat. The lower grids of the three sets in the top chamber are also diagonally arranged in a similar manner, but the remaining two are straight grids to facilitate thawing off as their primary function is air cooling.

The fans are driven by vairable speed direct coupled motors and as the supply is alternating current special commutator motors had to be installed.

The object of installing so many fans is to secure complete isolation of the different pairs of chambers, so that the possibility of taint penetrating from one to another is extremely remote if the chamber walls are impervious as in this construction.

The insulation of the entire building is compressed cork slab set in bitumen. In the case of Capetown, Portland cement was used, as this plant only necessitated temperatures above freezing.

At Durban, however, temperatures much below freezing are required for meat, and Portland cement under these conditions might crack along an isothermal surface due to the moisture diffusing inwards through the cement and then freezing. Mastic bitumen, being thoroughly waterproof, is free from any such risk and moreover assists in making the walls non-pervious to taint.

The cooling medium used throughout is calcium brine on a two temperature system.

This was selected in preference to direct expansion for two reasons. First, the accurate control of temperature for chilled meat. Second, the ease with which brine can be used as a " cold " accumulator to bridge over between running periods of the machines.

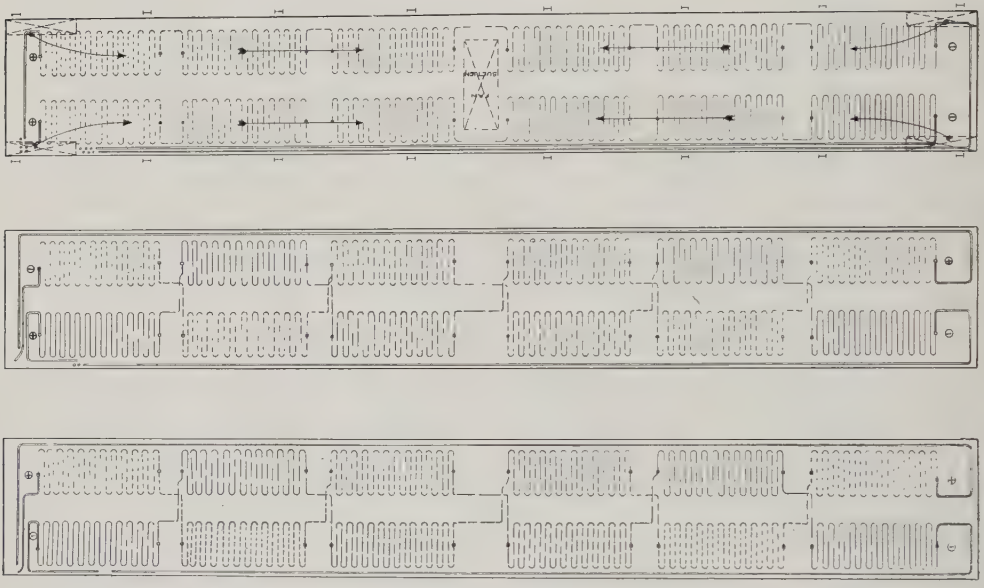


Fig 27.—Arrangement of cooling grids in each upper chamber and direction of air circulation. (The three sets shown are superimposed.)

Experience has shown that engine room costs are excessive with very light loads such as will inevitably occur at Durban at the beginning and end of the season, so that a plant which can be operated intermittently by two shifts instead of three has distinct economic advantages.

To obtain the necessary reserve submerged type evaporators were selected, although shell and tube coolers are more usual and would be slightly cheaper and simpler. The evaporators consist of two drums built up in three sections, diameter 11 ft. 6 in. and 10 ft. respectively; one contains 7 nests of 5 concentric coils, the other 7 nests of 4 concentric coils. Each nest is fed by a liquid ammonia lead from an accumulator which, in turn, is supplied by a liquid main from the engine room. The connections are so arranged that the coils may be operated flooded.

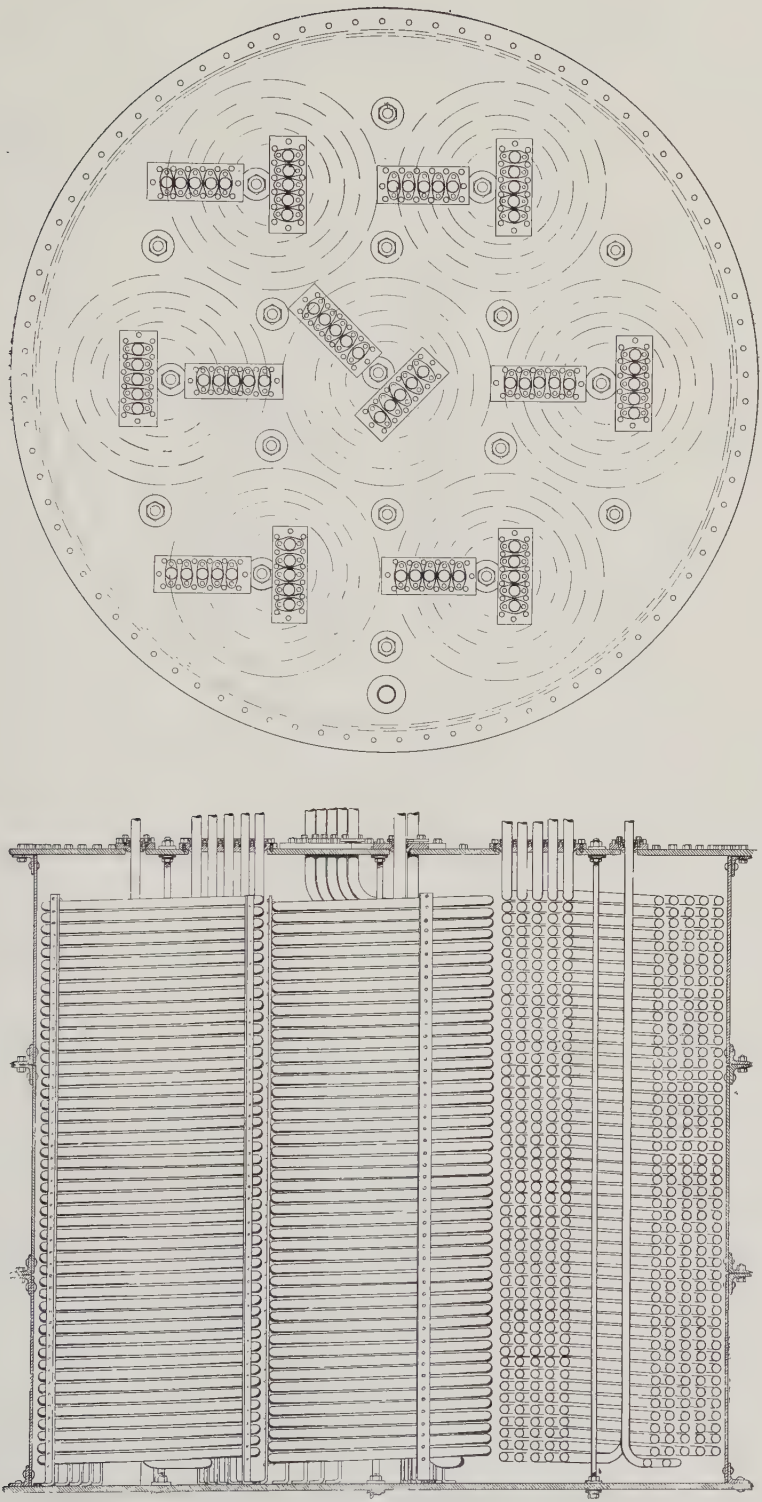


Fig. 28.—Evaporator tank and coils.

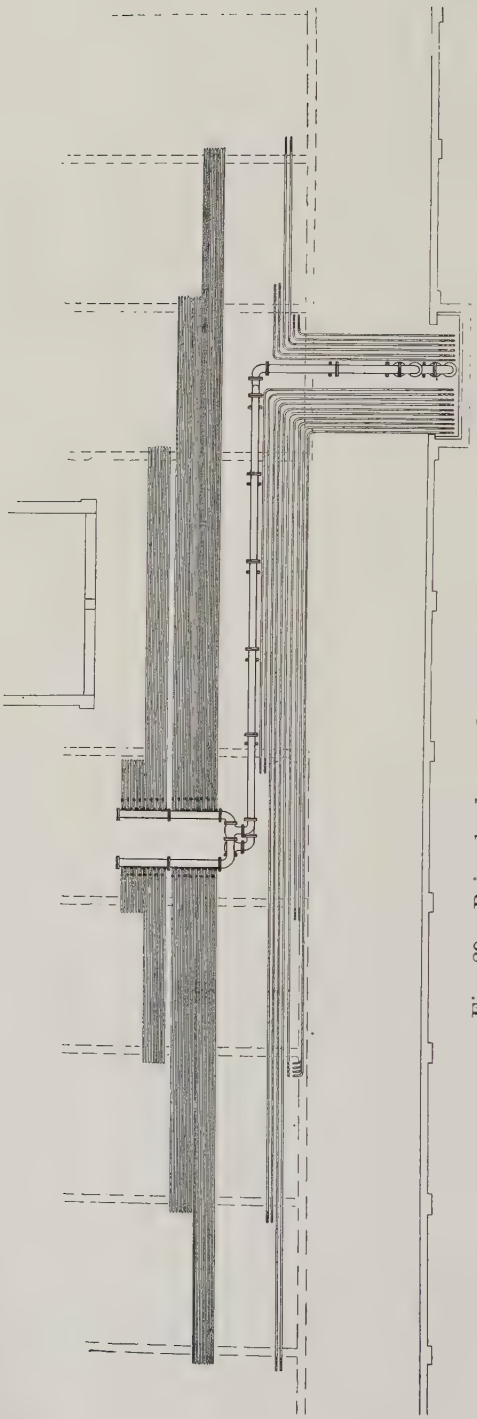


Fig. 29.—Brine leaders and returns above cooling chambers.

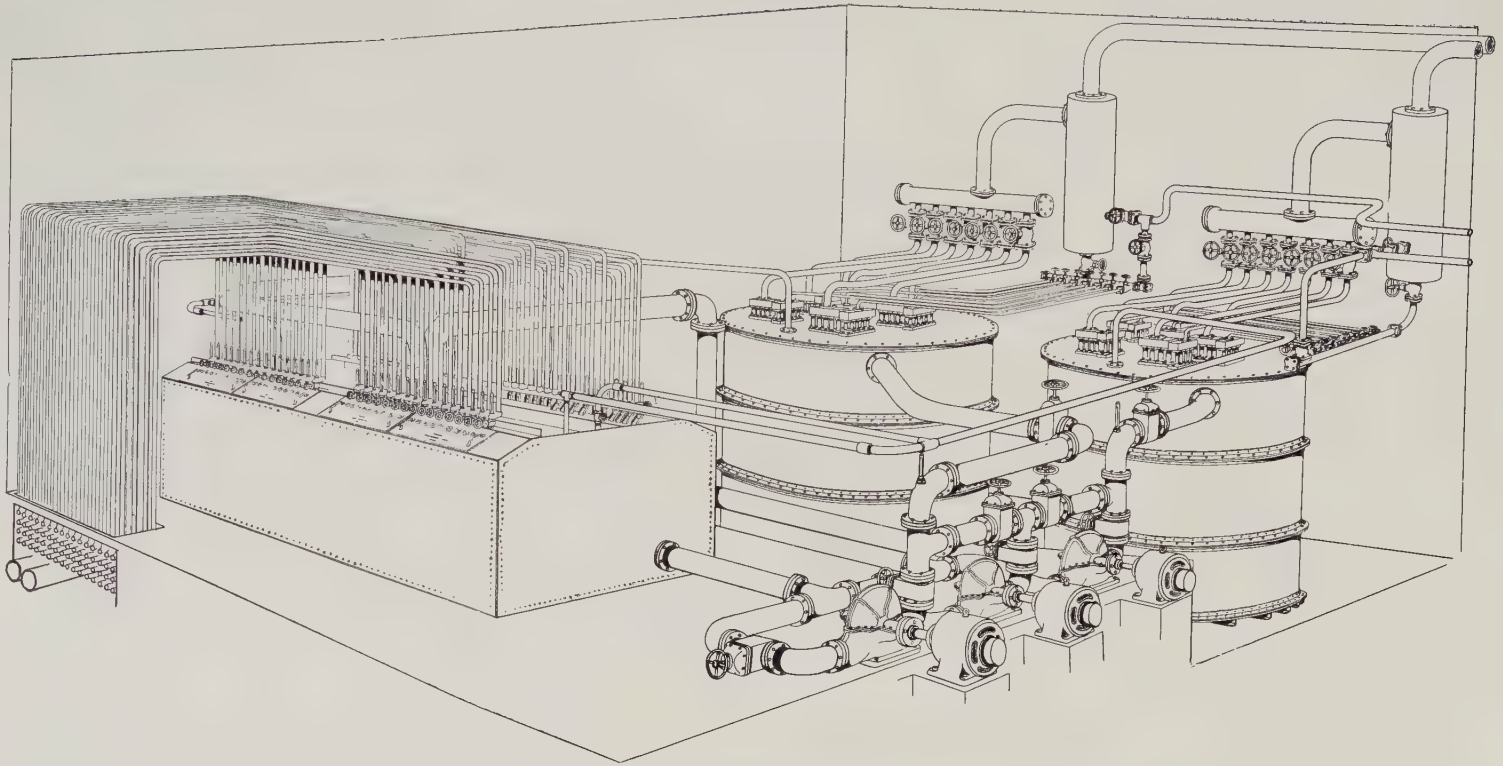


Fig. 30.—Evaporator Room showing ammonia and brine corrections.

The brine returns empty into a two sectioned return tank with the usual control valves, thermometers and tip-over shoots. The evaporator tanks can also deliver into the return tank direct if necessary in order to agitate the brine in the evaporators when it is desired to cool off these tanks rapidly.

The two evaporators in the brine room are: one 6,500 gallons capacity, the other 5,000 gallons. The brine is delivered from these by three pumps through two 8 in. mains to the top of the building. Here the mains join four headers made up in pairs with " attemperator " cocks for each brine lead to the chambers.

All returns, sixty-four in number, are carried down to the brine room and deliver into the return tank. The entire regulation of the plant is thus convenient to the engine room staff.

The three pumps are single stage centrifugal type direct, coupled to electric motors. The shafts of the motors being extended so that these can be situated on the other side of the insulated wall in the main engine room.

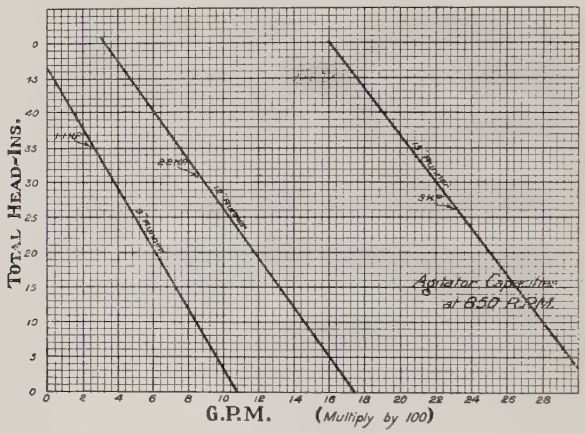


Fig. 31.

The general arrangement of the evaporator room with the various control valves is shown in Figure 30.

The evaporator tanks are sunk below ground level to avoid flooding over into the return tank when the pumps are stopped.

Ice Plant.

In order to meet the requirements of trawlers and railway vehicles it was decided to make provision at Durban for the manufacture of ice and a twin compartment tank is installed to manufacture 20 tons by day of clear ice in 100 lb. blocks. The older designs of ice tank had hairpin coils distributed along the tank and a small agitator projecting from one bulkhead for stirring, a heat transfer of 15 B.T.U.'s per sq. ft. per degree mean temperature difference per hour being the usual performance for the evaporating coils.

Considerable improvement has taken place in the design of modern tanks, thanks to the investigations of York Shipley. The conclusions, drawn from their experiments, are of interest and may be briefly summarised:—

(1) The brine velocity through the can spaces does not affect the freezing time materially as long as this velocity is above a certain minimum, i.e. velocities 5 to 75 ft. per minute produce no appreciable change.

(2) The brine temperature is the main element affecting freezing time. Increasing the brine velocity in the cam spaces to three times normal only decreases freezing time by 3 or 4 per cent. In other words increased heat transfer cannot be obtained through higher velocity.

(3) Long coils are not as effective as short ones provided the liquid could be fed to the pipes evenly and discharge end is not restricted.

(4) Increasing the brine velocity over the expansion coils by placing the coils in a separate trunk leads to the best results.

These authorities give the following figures as illustrating the data obtained with different types of coil placed in a central trunk.

	A.	B.	C.	D.
Feet of 1¼-in. pipe	500	500	500	500
Suct. Pressure. G	19·6	21·2	18·9	21·5
Brine Vel. Ft./Min.	133	133	133	133
Tons Refrig.	7·3	9·0	12·0	15·7
B.T.U. Transfer	43	68	66	120

A.—Coil of pipes made up horizontally.
B.—Same coil divided into two halves.
C.—Grid made of two vertical headers at either end with straight runs of horizontal pipe between headers—25 feet.
D.—Grid made in 'S' form, 20 pipes joining two horizontal headers. All coils working flooded condition from accumulator 12 feet above the top of coils feeding through large bore pipe, return suction passing through the accumulator.

Owing to some inconsistencies in the performances of these grids due to gas striking the end of the pipe in the top header the latest type of grid used differs considerably from any of the above and is made up in the form of horizontal "V.'s" joining the top and bottom header. Heat transmission up to 152 B.T.U.'s are claimed for this design with the advantage that the length of pipe is constant whatever the size of the tank.

The dimensions are in commercial practice apparently figured on the bases of 75 B.T.U.'s allowing a big margin of safety over and above the maximum capabilities.

From these experiments it is evident that given a fairly high brine velocity very substantial improvements are possible by attention to fundamental design of evaporating surfaces, the problem, in fact, is strictly analagous to that of the modern high duty steam boiler of water tube type with liquid brine as a heating medium instead of hot flue gases.

The advantage of high heat transmission is obvious when the power consumption of the brine agitator is calculated. The horse power curves are shown in Figure 31.

A minimum of 45 G.P.M. per ton is recommended. This quantity at 36 in. head will require a horse power of 1/8th to 1/5th h.p. per ton on the agitator shaft depending on the size of the impeller. This represents at the higher value 10 per cent. on the horse power required to produce a ton of ice under average conditions. Attention to this aspect is therefore fully justified.

In the case of the tank installed at Durban the designer has had in mind these modern developments and to some extent based his ideas accordingly. The tank is in two symetrical compartments on either side of an evaporator trunk containing the coils. Each com-

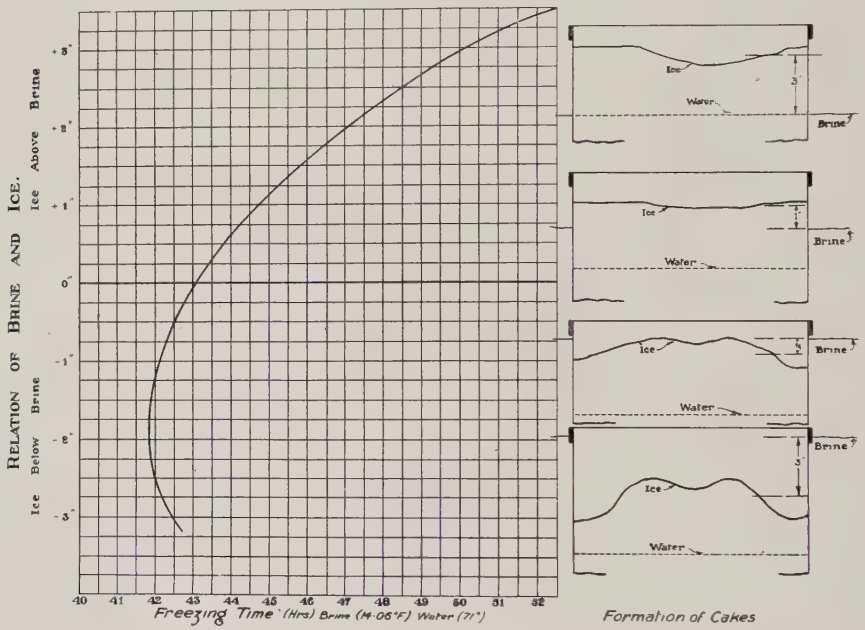


Fig. 32.—Influence if water level in ice can on freezing time. (York Shipley.)

partment contains eighteen group frames holding 12 cams for 100 lb. blocks. The evaporating surface consists of 10 coils arranged as horizontal narrow hairpins each having 390 ft. of 1¼ in. pipe. This allows 195 feet per ton as compared with the average value of 60 feet per ton recommended by York Shipley.

The coils are fed with ammonia from an accumulator about 2 feet above the tank through ½ in. valves. These valves are probably unduly small, as there is a risk, with constricted flow from the accumulator, of slopping over back on the machine especially as the accumulator has no float control.

The brine agitator is of vertical type and driven by an electric motor consuming 7 h.p., the effective brine head being 9 in. Rough calculation shows for these conditions a brine circulation of 3,250 gallons per minute and a velocity of over 270 feet per minute. This

quantity and velocity is very much greater than the optimum requirements as there is no advantage in high velocity around the cans and this high power consumption of the agitator increases the cost of the ice by adding 12 per cent. to the energy cost per ton.

The tank could probably be improved by baffling the area of the coil trunk so that the requisite velocity is obtained with a much smaller total circulation and decreased power on the agitator.

These new tank designs have many incidental advantages, compactness, simplicity and smaller difference in brine level from end to end of the tank. With the old type of agitator two circuits for circulation were arranged around the cans; this gave rise to several inches of brine head towards one end of the tank and the can frames had to be set out of level or the whole tank tilted in erecting. The brine level relative to the water level in the can is important inasmuch as it affects the appearance of the finished ice block and influences the freezing time; ice two inches above the brine level increases the freezing time four hours. The effect of submergence on both factors has been well illustrated by York Shipley in Figure 32.

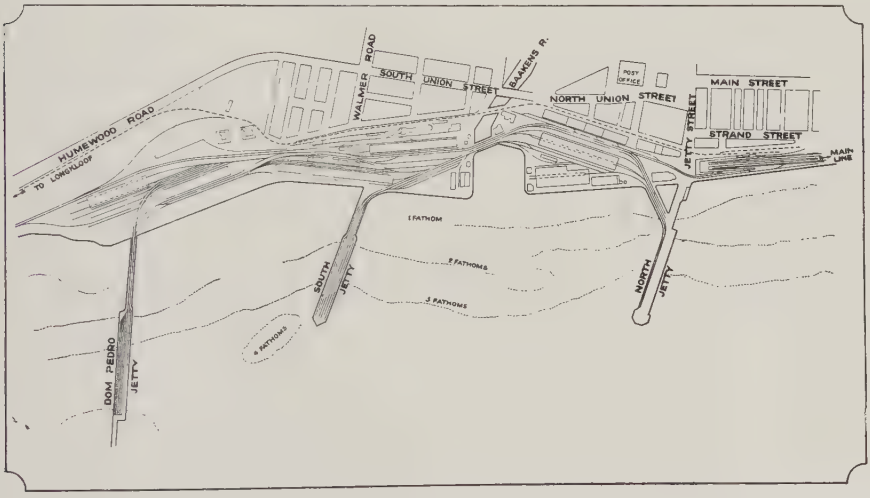


Fig. 33.—Port Elizabeth jetty system.

The water used for making ice is the town supply and in order to obtain a clear block air agitation is used. The air supply is from a constant speed direct coupled compressor controlled by automatic suction valves.

The compressed air is passed through a dehydrator containing cold brine circulated by a centrifugal pump from the main ice tank The can groups are connected to two main headers by unions and rubber pipes which are detached before lifting. All cans have permanent nozzles in the base.

The tank is served by an overhead crane with electric lift on traverse.

The crane is arranged to handle a group of twelve cans at a time, but two complete thawing tanks and tippers are provided opposite the appropriate section of the tank.

Port Elizabeth.—The problem of pre-cooling fruit at Port Elizabeth presents special difficulties. As already stated this port is an open roadstead subject to very rough weather. All cargo is handled by lighters from jetties. The fruit traffic arrives via standard gauge railway and also a 2-foot gauge system from the Longkloof and Gamtoos Valleys. Owing to the configuration of the ground the narrow gauge does not obtain access to the jetties and all fruit has to be transhipped.

Various suggestions have been made for the erection of a pre-cooling plant but pending the completion of the breakwater now under construction all these schemes are in abeyance and the position is at least partially met by the use of four refrigerated lighters.

The lighters are steel vessels 81 feet between perpendiculars, 20 ft. 6 in. beam. These dimensions are considered to be on the small side for an efficient unit but, the size is strictly limited by risk of damage when the lighters range alongside the steamers in a heavy swell.

The hulls of the lighters are built of $\frac{3}{8}$in. plate on Z frames at 1 ft. 8 in. centres. Web frames are omitted from the design and compensation obtained by the use of solid round columns as this method simplified insulation. A 22 in. elm fender $3\frac{1}{2}$ in. thick extends all the way around the vessel for protection. The insulation is kept clear of the vessel's skin by $1\frac{1}{2}$ in. by $1\frac{1}{2}$ in. timber faced with $\frac{7}{8}$ in. T. and G. board. This secures the insulation from wet in the event of a plate being sprung in a minor collision with the jetties or steamer.

The insulating material is granulated cork 6 in. thick and this is faced on the inside with 3/16ths in. galvanized " Armco " iron sheets fastened with countersunk screws to 2 in. by $\frac{3}{8}$ in. butt straps. The ceiling is of similar construction with 9 in. granulated cork faced with galvanized iron.

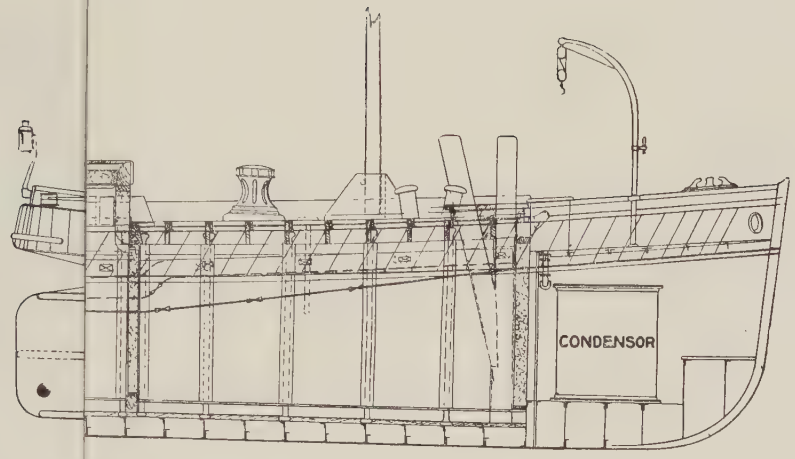
The floor is laid with two thicknesses 3 in. compressed cork slab on the double bottom and this cork is again faced with asphalt covered with galvanized " Armco " iron checker plate.

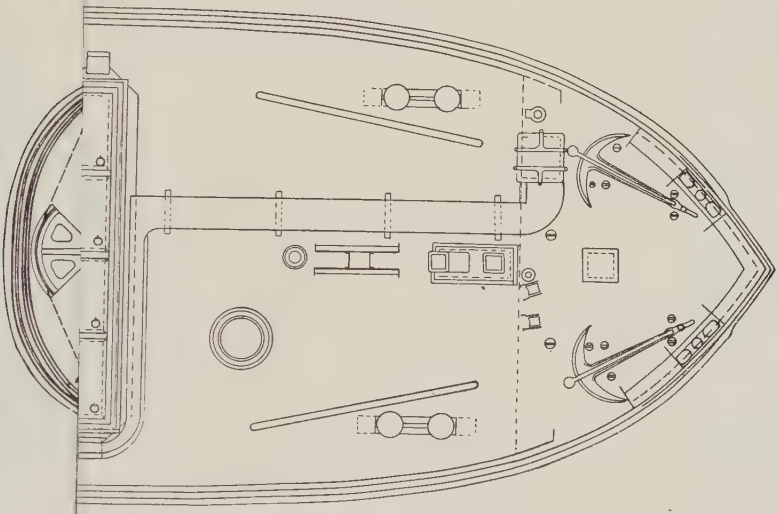
The hold is divided into three chambers, access being obtained by doors 6 ft. 6 in. high 4 ft. wide from the centre chamber under the hatch. This hatch is 22 ft. 6 in. by 14 ft.

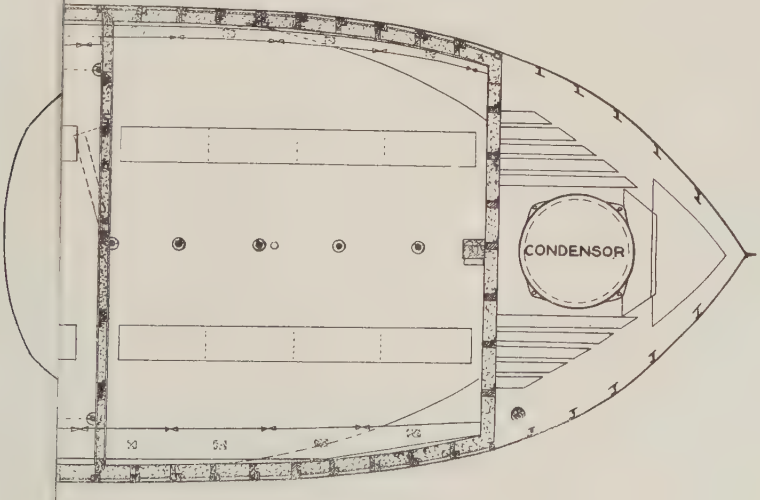
The cooling plant is installed on deck, the deck plates being thickened up to $\frac{3}{4}$ in. for its support and the weight further distributed by two rolled steel channel bearers across the deck.

The compressor is a twin-cylinder $7\frac{1}{2}$ in. by $7\frac{1}{2}$ in. ammonia (miniatures of the Capetown plant) driven by a single cylinder 25 h.p. two-stroke Vicker's Petter oil engine, running at 375 r.p.m. An extension of the engine shaft driving the water circulating pump and fan.

The condensor is a submerged marine type consisting of 1,100 feet $1\frac{1}{2}$ in. solid drawn tubing. This is situated in the peak. The air cooler is enclosed in a small compartment aft and is of cross coil type with 1,250 feet of $1\frac{1}{2}$ in. bore galvanized pipe. The air circulation from this cooler is subdivided into three ducts leading to each chamber with separate valve controls. A branch pipe is also led up through the deck in the event of it being required to supply cold air to an auxiliary insulated lighter brought alongside.


CONDENSOR




CONDENSOR

To secure regulation the compressor speed can be varied by about 15 per cent. and in addition clearance pockets are provided on each ammonia cylinder. These can be adjusted to vary the performance of the compressor.

Temperatures are read in the usual way with drop thermometers in tubes but a dial type mercury in steel thermometer is installed in the delivery air duct to show a continuous indication of the functioning of the cooler.

These four lighters have functioned very well, but the size limitation placed upon them by local conditions has deprecated their economic value. Their capacity could with advantage be doubled without perceptible increase in size of plant or running cost.

With regard to mechanical features it is considered that four cycle engines would be preferable and another modification which

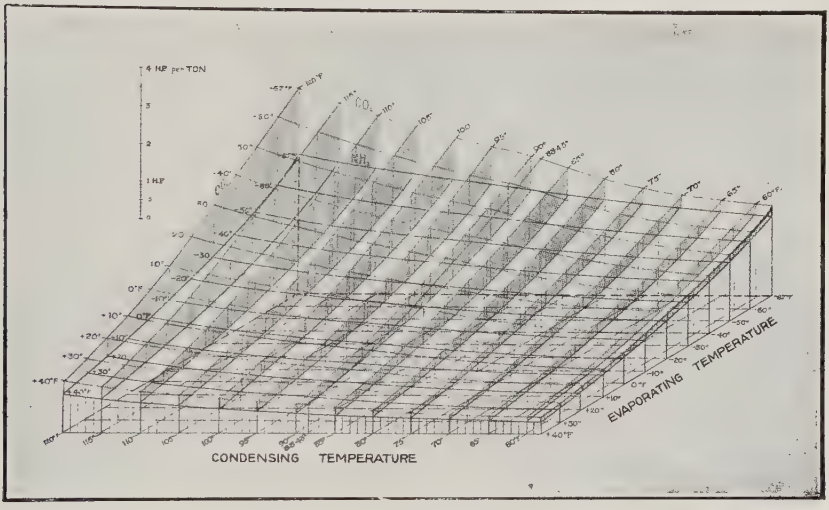


Fig. 35.—Power consumption of ammonia and carbonic acid refrigerating machine under various working conditions. (A. E. Williams.)

could be made with advantage is to use submerged centrifugal pumps, as the wear and tear on the present pumps is excessive in view of the amount of solid matter in suspension in sea water.

East London.—There are no special pre-cooling facilities at East London at present. This port is situated at the mouth of the Buffalo River. A certain amount of wharf front is available on the banks of the river, but the existence of a sand bar across the entrance prohibits the entrance of any deep draught vessels.

Lighters have, therefore, to be used for mail boats and similar vessels.

Harbour improvement work is proceeding steadily, but it will probably be many years before the trade of the hinterland can justify incurring the very heavy expenditure necessary to make it a modern deep water port.

A small pre-cooling plant serving insulated lighters or fully refrigated lighters will have to be provided at East London soon.

Refrigerating Plant.

The selection of machines at Capetown and Durban was governed by much the same limitation. The engine rooms were naturally restricted as space near the quay is always valuable. Again electric drive was the obvious prime mover, as this power was available. These two factors at once implied the use of medium speed direct coupled machines.

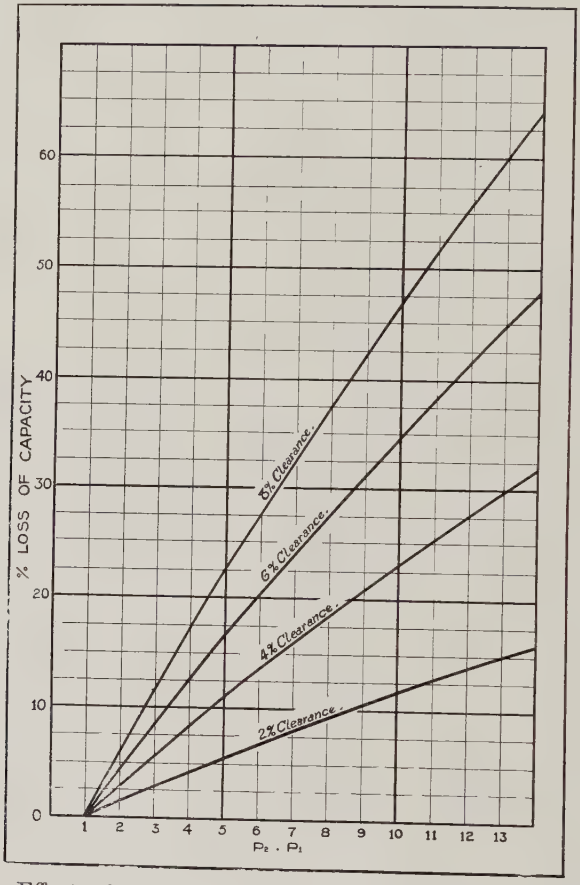


Fig. 36.—Effect of varying amount of clearance or performance of refrigerating machine.

The choice of refrigerant was governed by prevailing temperatures and practical consideration. The decision rested between ammonia and carbonic acid gas. Inspection of Chart (Figure 35), due to A. E. Williams, Illinois, U.S.A., will clearly demonstrate the theoretical advantages of ammonia.

The horse power per ton is shown as vertical ordinates and corresponding evaporator and condensor temperatures projected along the other two axis. At low condensor temperature the advantage of

ammonia is slight but as the temperature increases the relative efficiency is greater, particularly when CO_2 approaches the critical point.

There was another factor in favour of ammonia for the Capetown plant, and that was the fact that it was desired to make the cooling direct expansion in order to secure quick response to rapid fluctuations in load when large quantities of fruit arrived for pre-cooling and also allow quick thawing down of snow on the coils by the use of hot gas from the condensor. Direct expansion is not practical with CO_2 owing to the excessive pressure throughout the system and, therefore, heavy gauge of all piping.

From the constructional point of view the low evaporator pressure of ammonia permits the use of single acting machines with enclosed crankcase subjected to the suction pressure instead of a piston rod with gland in the case of carbon dioxide.

The design of high speed single acting machines is a comparatively new subject. The gas velocities are greatly increased over the usual practice and very light valves of adequate area must be employed.

The usual mushroom type of valve for slow speed machines has been adopted in smaller units but the growing practice is the use of ring plates of concentric or multiple unit type. This class of valve requires a retaining cage to limit the travel and this immediately increases the clearance volume in the cylinder. It has been stated even in modern publications that clearance is unimportant. This assertion is a serious fallacy without strict qualification.

Clearance losses depend fundamentally on the compression ratio; in temperate climates with cold condensing water slight changes in clearance might be insignificant, but under tropical conditions the loss of machine capacity with increase in clearance will be of great importance.

Figure 36 will make this point clear.

In typical machines the clearance varies from $2\frac{1}{2}$-5 per cent., and in extreme cases 8 per cent. has been used.

It will be seen that within practical ranges of temperature such as 85° cooling water and zero brine (for 8 per cent. clearance) the machine capacity has dropped 30 per cent. below the calculated value for no clearance.

It has been suggested that these tropical conditions could best be met by compounding. Unfortunately, the design of compound machines does not lend itself to single acting high speed types and our experience of fairly large units on board ship would indicate that the complications and cumbersome nature of the machine is not justified in practice.

The machines selected were: At Capetown, two Hall's $16\frac{1}{2}$ in. bore by 12 in. stroke twin cylinder, and at Durban, two Stern's $13\frac{1}{2}$ in. bore 9 in. stroke, one with four and the other with three cylinders. The power supply at Capetown was 550 volts D.C. for all dock machines. This was, therefore, utilized.

The existence of a D.C. service made the use of variable speed motors a simple and desirable matter, and a speed variation of 140 to 220 revolutions per minute is provided for. In conjunction with direct expansion coolers this flexibility is a great asset.

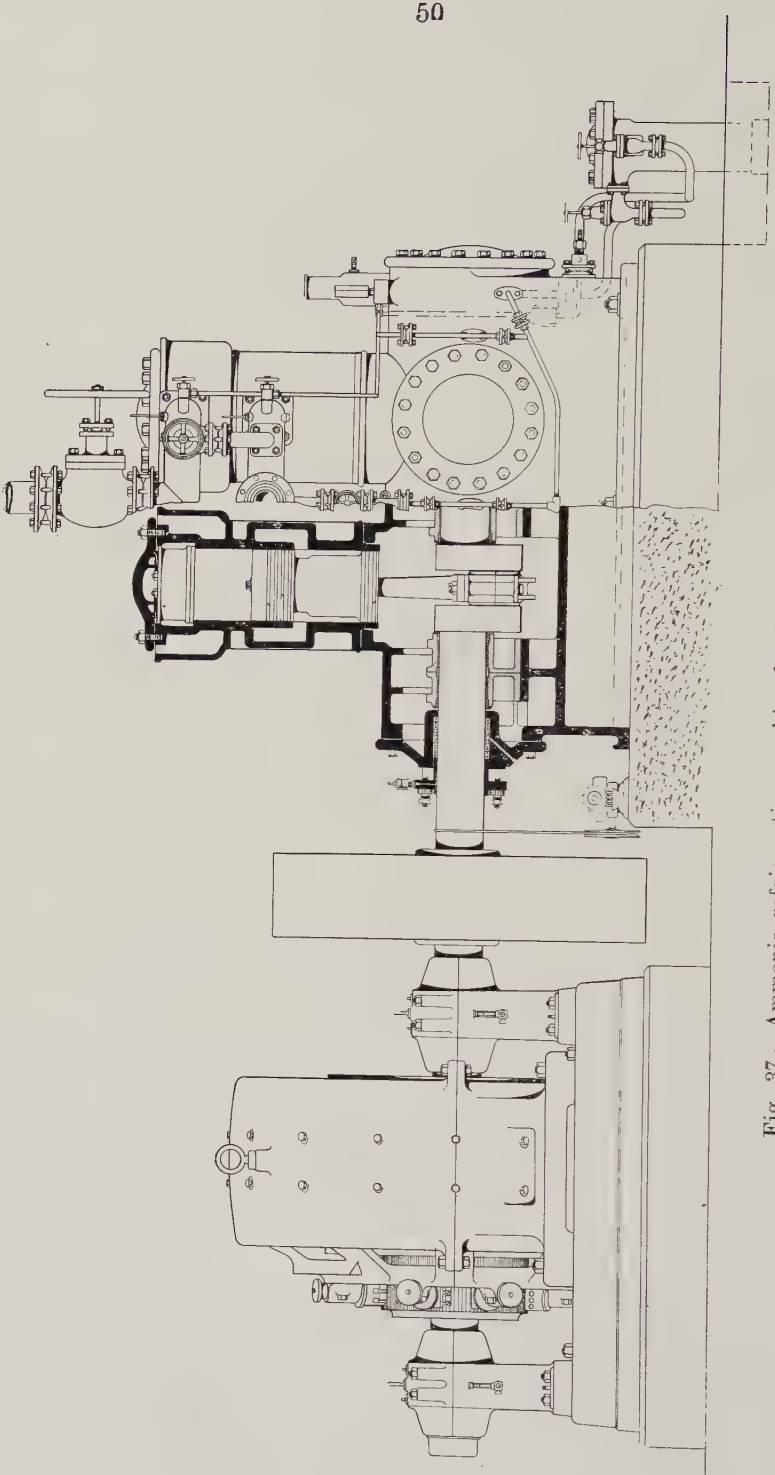


Fig. 37.—Ammonia refrigerating machine by J. and E. Hall, Ltd.

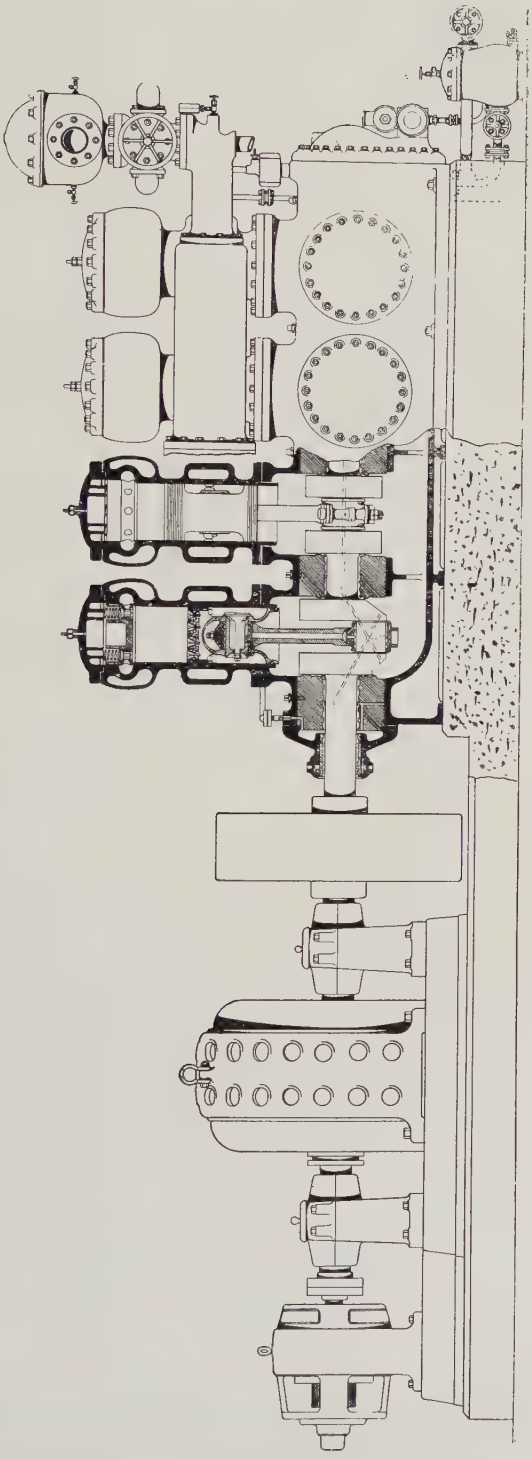


Fig. 38.—Ammonia refrigerating machine by L. Stern, Ltd.

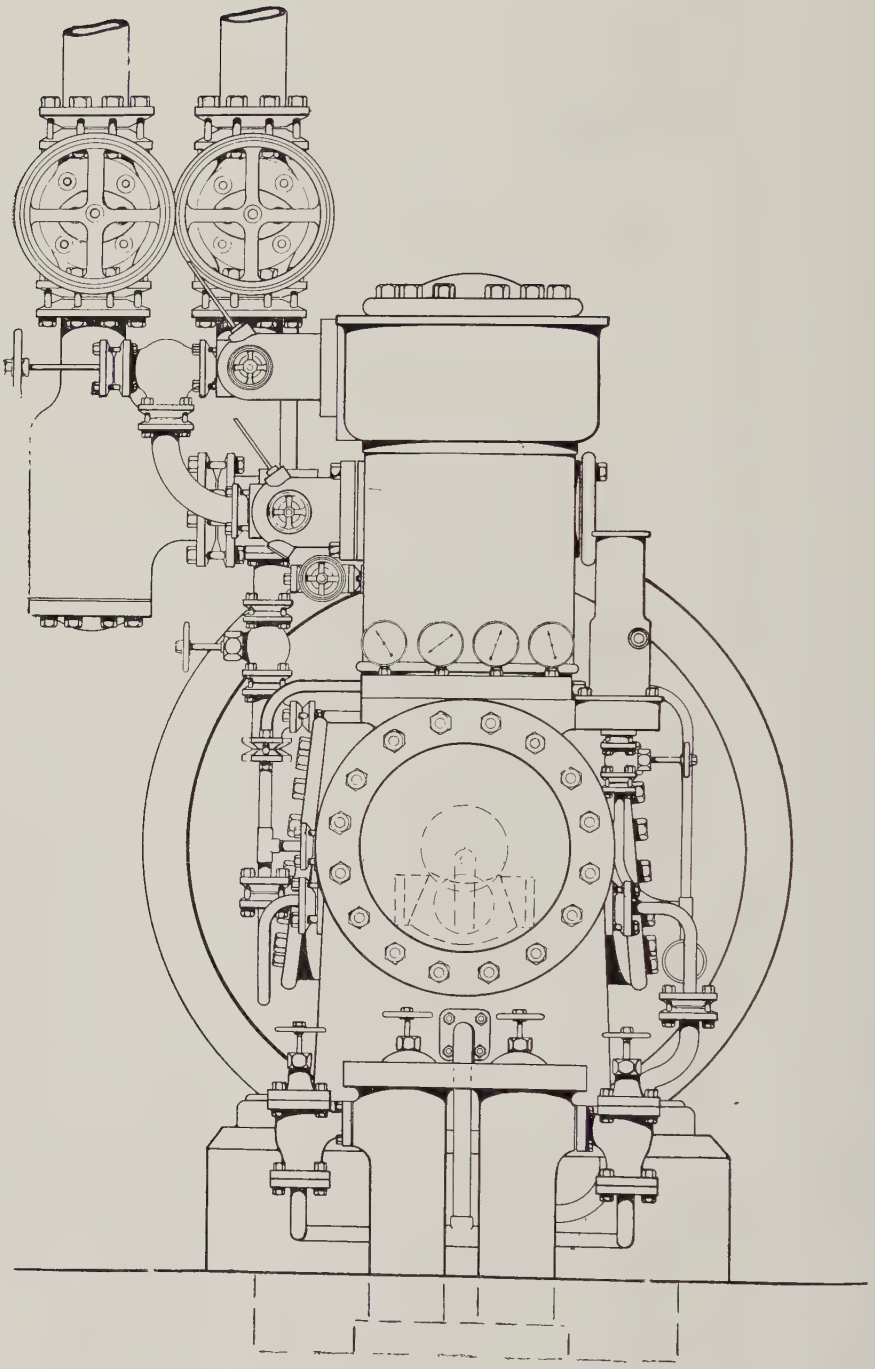


Fig. 39.—End elevation of Hall machine

A side elevation of these machines is shown in Figure 37. Each cylinder is water jacketed and forced lubrication from a plunger pump on the end of the crankshaft is used. All bearings except the gudgeon pin are white metal, but the bush is bronze. The pistons are

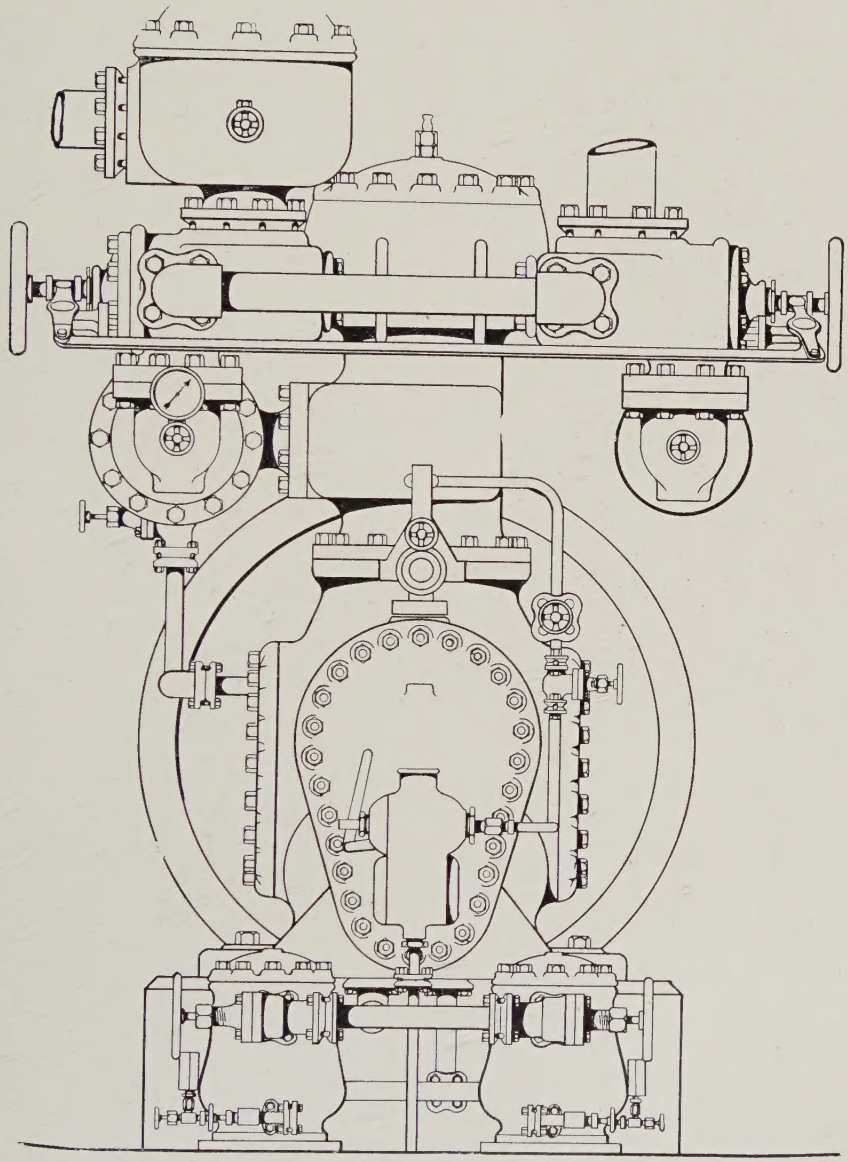


Fig. 40.—End elevation of Stern machine.

trunk type, fed with gas through cylinder ports. Both pistons and cylinder head have ring plate valves arranged in concentric circles. Each ring, however, is held on its seat by a series of thimble springs. These apparently are an important feature of the design as the valves

have been an unqualified success compared with the results of previous similar designs without spring loading as the outer rings in this case tended to do all the work.

The delivery valve plate is spring loaded to act as a safety head in case liquid is drawn over.

A large bore by-pass is provided for starting and this pipe has the additional fitment of a safety disc which is designed to collapse in the event of excessive delivery pressures such as excessive condensor temperature or an error in valve manipulation in starting. Although the latter is a remote possibility as the suction and delivery valves are interlocked.

The Durban supply is alternating current, the machines are driven by auto-synchronous motors. Synchronous speed 250 r.p.m. The four-cylinder machine is shown in side elevation in Figure 38.

The cylinders are provided with safety heads and trunk pistons; forced lubrication from a plunger pump is provided. All bushes, including the gudgeon pin, are white-metalled. The valves are arranged as units, 14 suction in the piston and 9 delivery in the head, each having one ring plate. No springs being fitted to the suction valves.

Our experience with these and a number of similar machines leads us to recommend special care in the design to incorporate ample valve area to cope with the flow of gas. Water cooled heads to minimize overheating and carbonizing of lubricating oil, especially in the initial cooling down of the system when suction pressures are unusually high. All designs at present appear to carry excessive quantities of lubricating oil in the crankcases (about 40 to 60 gallons). This oil dissolves ammonia and any sudden change in operating conditions leads to frothing and carrying over of oil into the system.